4

Environmental Consequences of Repository Construction, Operation and Monitoring, and Closure

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

4. ENVIRONMENTAL CONSEQUENCES OF REPOSITORY CONSTRUCTION, OPERATION AND MONITORING, AND CLOSURE

This chapter describes short-term environmental consequences that could result from the implementation of the Proposed Action, which is to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. *Short-term* refers to the period from the beginning of construction through final repository closure, and includes project phases of construction, operation and monitoring, and closure. For purposes of analysis, the repository would remain open from 115 to 341 years from the beginning of construction to final closure, depending upon the operating mode and operating parameters selected. Chapter 5 discusses the environmental consequences of long-term repository performance—that period out to 10,000 years and beyond after repository closure. Chapter 6 discusses the environmental consequences of transportation, and Chapter 7 discusses the environmental consequences of the No-Action Alternative.

Section 4.1 describes potential environmental impacts from required activities at the repository site to implement the Proposed Action, including continued site investigations (called *performance confirmation*), offsite manufacturing of repository components (for example, disposal containers and drip shields) and shipping casks, and a floodplain assessment. The implementation of the Proposed Action would require performance confirmation in support of a U.S. Nuclear Regulatory Commission licensing process. Section 4.2.1 describes potential environmental impacts of retrieval if such an option became necessary. Section 4.2.2 describes the environmental impacts associated with the receipt of waste prior to the start of emplacement.

The U.S. Department of Energy (DOE) has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative for the Secretary of Energy's consideration, along with other factors required by the Nuclear Waste Policy Act, as amended (NWPA), in making a determination on whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. This chapter contains information about short-term environmental impacts that would be directly associated with the construction, operation and monitoring, and eventual closure of a repository.

4.1 Short-Term Environmental Impacts of Performance Confirmation, Construction, Operation and Monitoring, and Closure of a Repository

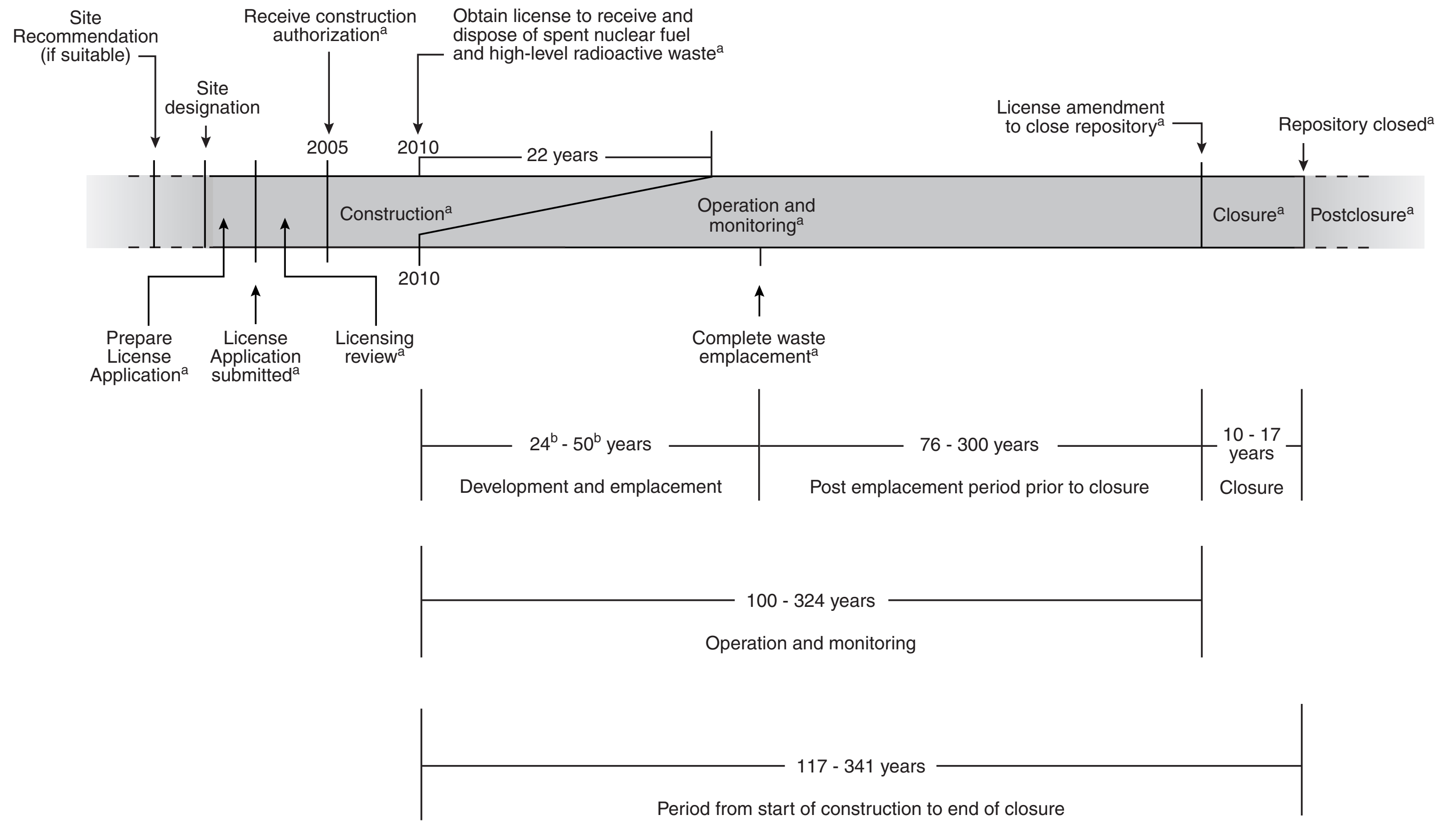
This section describes the short-term environmental impacts associated with the Proposed Action. DOE has described the environmental impacts according to the phases of the Proposed Action—construction, operation and monitoring, and closure—and the activities (some of which overlap) associated with them. The following paragraphs summarize the phases and activities that would occur, and the operating modes evaluated in this environmental impact statement (EIS). Chapter 2 describes these operating modes in detail. Figure 4-1 shows the expected timeline for these phases. In addition, this section describes the impacts from the testing and performance confirmation activities that DOE would perform before the start of repository construction in support of a Nuclear Regulatory Commission licensing process. These activities, which would continue through repository closure, could require surface or subsurface excavations and drill holes, testing, and environmental monitoring. As these activities revealed more scientific data, DOE would expect their level of effort to decrease.

PRECONSTRUCTION TESTING AND PERFORMANCE CONFIRMATION ACTIVITIES

The preconstruction testing and performance confirmation program would continue many of the same types of activities performed during site characterization—tests, experiments, and analyses—for as long

Main Index

Vol 1 Index



a. If Yucca Mountain is approved.

b. Analysis without aging assumed that waste emplacement would occur over a 24-year period and analysis with aging assumed that waste emplacement with commercial spent nuclear fuel aging would occur over a 50-year period.

Note: See Table 2-2 for range of emplacement, preclosure ventilation, and closure durations.

Sources: Modified from DIRS 104523-CRWMS M&O (1999, Figure 1.5-1, p.1-3).

Figure 4-1. Monitored geologic repository range of milestones used for analysis.

as required. DOE would continue performance confirmation activities during all the phases of the repository project to evaluate the accuracy and adequacy of the information it used to determine with reasonable assurance that the repository would meet the performance objective for the period after *permanent closure*.

INITIAL CONSTRUCTION PHASE (STARTING IN 2005, LASTING 5 YEARS)

The construction of facilities would begin when and if the Nuclear Regulatory Commission authorized DOE to build the repository. For analysis purposes, this EIS assumed construction would begin in about 2005. Site preparation, including the layout and grading of surface facility locations, would be part of the initial construction activities; DOE would construct new surface facilities or modify facilities built to support site characterization. Most surface facility construction would be completed during this phase, with the exception of the solar facility and aging pads, if built. Initial subsurface construction would excavate access mains, ventilation shafts, and the first emplacement drifts and prepare them for the start of emplacement activities, assumed for analysis purposes to begin in 2010. As mentioned above, performance testing and confirmation activities would be ongoing during this period.

OPERATION AND MONITORING PHASE

The operation and monitoring phase would last 100 to 324 years and would consist of an operations period and a monitoring period. The EIS analyses assumed that repository operations would begin in 2010, assuming DOE received a license from the Nuclear Regulatory Commission to receive and dispose of spent nuclear fuel and high-level radioactive waste. The operations period would include continued development (excavation and preparation for use) of the subsurface repository, receipt and handling of spent nuclear fuel and high-level waste in surface facilities, and emplacement of these materials in the completed portions of the subsurface repository. Development activities would last 22 years for all operating modes, concurrent with handling and emplacement. Handling and emplacement activities would last 24 years for the higher-temperature operating mode and for the lower-temperature operating mode if surface aging was not used. If surface aging was used, the operations period would last 50 years.

Monitoring of the emplaced material and maintenance of the repository would start with the first emplacement of waste packages and would continue through the closure phase. After the completion of emplacement, the monitoring period would begin, during which monitoring would be the primary activity. DOE would maintain the repository in a configuration that would enable continued monitoring and inspection of the waste packages, continued investigations in support of predictions of long-term repository performance (the ability to isolate waste from the accessible environment), and the retrieval of waste packages, if necessary. This period would last from 76 to 300 years. The first 3 years of the monitoring period would include the radioactive decontamination of surface facilities used for handling radioactive materials. Facilities would be decontaminated so there would be no chance for release of contamination when they were in standby mode during the monitoring period, and they would be ready for either demolition during the Closure Phase or for use as part of a retrieval contingency.

Future generations would need to decide whether to continue to maintain the repository in this open monitored condition or to close it. However, the Department expects that a repository could be maintained in an open monitored condition, with appropriate maintenance, for the time periods evaluated in this chapter. For this analysis, the EIS evaluates closure starting 100 years after the start of emplacement for the higher-temperature operating mode, and 149 to 324 years for the lower-temperature operating mode.

As mentioned above, DOE would continue its performance confirmation activities during the development, waste emplacement, and monitoring activities.

CLOSURE PHASE (LASTING 10 TO 17 YEARS)

Repository closure would occur after DOE applied for and received a license amendment from the Nuclear Regulatory Commission. Closure would take 10 years for the higher-temperature operating mode and from 11 to 17 years for the lower-temperature operating mode, depending on the operating parameters that had been employed. The closure of the repository facilities would include the following activities:

- Removing and salvaging valuable equipment and materials
- Backfilling the main drifts, access ramps, ventilation shafts, and connecting openings and sealing underground-to-surface openings
- Constructing monuments to mark the area
- Decommissioning and demolishing surface facilities
- Restoring the surface to its approximate condition before repository construction
- Continuing performance confirmation activities as necessary

REPOSITORY OPERATING MODES

As discussed in Chapter 2, the repository design is conceptual and continues to evolve. This evolution will continue throughout the process established by the Nuclear Regulatory Commission for license application and construction authorization. To present the range of short-term environmental impacts that could occur, DOE has selected a range of higher-temperature to lower-temperature operating modes for evaluation in this EIS. The higher-temperature operating mode has an established set of operating parameters (DIRS 153849-DOE 2001, all). The desired characteristics for a lower-temperature operating mode could be reached under a variety of operating parameters, and was evaluated using a range of parameter values affecting repository size and ventilation characteristics, number and spacing of waste packages, and length of activity periods. Elsewhere in this EIS (Chapter 6 and Appendix J) the potential impacts of specific transportation and fuel packaging options (Appendix F) are examined. Where transportation and spent fuel packaging options may make a difference in repository impact analysis, legal-weight truck transportation option and/or uncanistered spent fuel packaging have been assumed because they typically result in the highest potential impacts. There are a few exceptions to this general rule, for example, where use of canisters for fuel packaging would result in additional waste. These instances are specifically identified where they occur in Chapter 4.

4.1.1 IMPACTS TO LAND USE AND OWNERSHIP

This section describes potential land-use and ownership impacts from the preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. DOE determined that information useful in an evaluation of land-use and ownership impacts should identify the current ownership of the land that repository-related activities could disturb, and the present and anticipated future uses of the land. The region of influence for land-use and ownership impacts is a land withdrawal area that DOE used for the EIS analysis. Congress would have to define the actual land withdrawal area. The analysis considered impacts from direct disturbances related to repository construction and operation. It also considered impacts from the transfer of lands to DOE control.

4.1.1.1 Impacts to Land Use and Ownership During Preconstruction Testing and Performance Confirmation and from Land Withdrawal

Preconstruction testing and performance confirmation activities would occur primarily on land managed by the Federal Government. As with site characterization, these activities would occur in the land withdrawal area that DOE analyzed in the EIS (see Section 3.1.1). DOE would seek to maintain the current administrative land withdrawal of 20 square kilometers (7.7 square miles), current right-of-way reservations N-47748 [210 square kilometers (81 square miles)] and N-48602 [about 75 square kilometers (29 square miles)], and the existing management agreement between the Yucca Mountain Site Characterization Office and the Nevada Operations Office (as described in Section 3.1.1) until Congress approved a permanent land withdrawal. The Nevada Operations Office operates the Nevada Test Site.

To develop the proposed Yucca Mountain Repository, DOE would need to obtain permanent control of the land surrounding the repository site. The Department believes that an area of approximately 600 square kilometers (230 square miles) on Bureau of Land Management, U.S. Air Force, and DOE lands in southern Nevada would be sufficient (see Section 3.1). Of the 600 square kilometers, approximately 210 square kilometers (81 square miles) comprise the right-of-way reservation noted above, with 180 square kilometers (70 square miles) remaining in public lands under the Bureau of Land Management's right-of-way agreement with DOE. As such, these lands are currently available for public use including mineral exploration and recreation. There are several current mining and mineral claims within the parcel that would be affected by withdrawal from public use. Such leases and unpatented mining claims could be withdrawn by the Bureau of Land Management or could be voided by an act of Congress that would withdraw the land for a repository. The current recreational use of the land under the Bureau of Land Management's right-of-way agreement could also be withdrawn by the Bureau or by establishment by Congress of a repository at Yucca Mountain.

Nuclear Regulatory Commission licensing conditions for a repository (10 CFR 60.121) include a requirement that DOE either own or have permanent control of the lands for which it is seeking a repository license. As noted above, portions of the area proposed for the repository are lands controlled by the Bureau of Land Management, the Air Force, and the DOE Nevada Operations Office.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Through legislative action, Congress can authorize and direct a permanent withdrawal of lands such as those proposed for the Yucca Mountain Repository. In addition, Congress would determine any conditions associated with the land withdrawal. Nuclear Regulatory Commission regulations require that repository operations areas and postclosure controlled areas be free and clear of all encumbrances, if significant, such as (1) rights arising under the general mining laws, (2) easements or rights-of-way, and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise. If Congress approved withdrawal of lands for repository purposes, any other use of those lands would be subject to conditions of the withdrawal.

Repository construction, operation and monitoring, and closure activities would require the active use of a maximum of about 6 square kilometers (1,500 acres, 2.3 square miles) composed of small noncontiguous areas within the larger 600-square-kilometer (230-square-mile) land withdrawal area used for purposes of analysis.

Chapter 2 describes activities that DOE would conduct in the Yucca Mountain site active-use area and the land withdrawal area.

The amount of land that DOE would need to support repository activities would vary little among repository operating modes. Most of the surface facilities and disturbed land would be in the South

Main Index
Vol 1 Index

Portal Development Area and North Portal Operations Area. Repository activities would not conflict with current land uses on adjacent Bureau of Land Management, Air Force, or Nevada Test Site lands.

4.1.1.2 Impacts to Land Use and Ownership from Construction, Operation and Monitoring, and Closure

During the construction and operation and monitoring phases, DOE would disturb or clear land for the repository and surface facility construction. The Department would use this land for surface facilities, performance confirmation activities, and excavated rock storage. DOE does not expect conflicts with uses on surrounding lands because repository operations would occur in a confined, secure area over which DOE would have permanent control. Furthermore, this is public land, much of which has been used for repository site characterization for nearly two decades.

As described in Section 4.1, surface activities associated with closure would include constructing monuments, decommissioning and decontaminating facilities, and restoring the surface to its approximate preconstruction condition. DOE could use material from the excavated rock pile to backfill the repository tunnels (excluding the emplacement drifts), and would contour the excavated material remaining after backfill and subsurface closure activities and cover it with topsoil. During closure, the Department would restore disturbed areas to their approximate condition before repository construction.

Surface disturbance for the higher-temperature operating mode would be 4.3 square kilometers (1,000 acres). Surface disturbance for the lower-temperature operating mode would range from 4.5 square kilometers (1,100 acres) to approximately 6 square kilometers (1,500 acres). The surface disturbance represents a small amount of the 600 square kilometers (150,000 acres) of land withdrawn for the repository. Therefore, there would be small impacts to land use due to the implementation of the Proposed Action.

4.1.2 IMPACTS TO AIR QUALITY

This section describes possible nonradiological and radiological impacts to air quality from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure. Appendix G provides more details on the methods used for air quality analysis.

Sources of nonradiological air pollutants at the proposed repository site would include fugitive dust emissions from land disturbances and excavated rock handling; nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter emissions from fossil fuel consumption; and fugitive dust emissions from concrete batch plant operations. DOE used the Industrial Source Complex computer program to estimate annual and short-term (24-hour or less) nonradiological air quality impacts (DIRS 103242-EPA 1995, all). Nonradiological impacts evaluated include those from four criteria pollutants: nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10}). In addition, potential impacts were evaluated for the possibly harmful mineral cristobalite, a form of silica dust that is the causative agent for silicosis and might be a carcinogen. The analysis did not quantitatively address the two other criteria pollutants, lead and ozone (see Appendix G, Section G.1). There would be no sources of airborne lead at the repository, and very small sources of volatile organic carbon compounds, which are ozone precursors. The analysis did make a general comparison to the pending National Ambient Air Quality Standard for particulate matter with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$), which has yet to be implemented (see Chapter 3, Section 3.1.2.1). DOE used these standards, among other air quality standards shown in Chapter 3, Section 3.1.2.1, in analyzing the nonradiological air quality impacts discussed in this section.

Radiological air quality impacts could occur from releases of radionuclides, primarily naturally occurring radon-222 and its radioactive decay products, from the rock into the subsurface facility and then into the ventilation air during all phases of the repository project. Radioactive noble gases, principally krypton-85, would be released from surface facilities during the handling of spent nuclear fuel. DOE used dose factors from DIRS 101882-NCRP (1996, Volume 1, pp. 113 and 125) to estimate doses to *noninvolved workers* (workers who could be exposed to air emissions from repository activities but who would not be directly associated with those activities) and offsite individuals from such releases.

The air quality analysis evaluated nonradiological air quality impacts at the potential locations of maximally exposed members of the public. It estimated radiological air quality impacts as the doses to maximally exposed individuals and populations of the public and to noninvolved workers. The analysis did not consider involved workers because they would be exposed in the workplace, as discussed in Section 4.1.7. Overall, the impacts to regional air quality from performance confirmation, repository construction, operation and monitoring, and closure would be small. Exposures of maximally exposed individuals to airborne pollutants would be a small fraction of applicable regulatory limits. For periods of 1 year or longer, maximally exposed individuals were assumed to be at the southern boundary of the land withdrawal area, the closest location they would be for long periods during repository activities.

4.1.2.1 Impacts to Air Quality from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities would generate particulate and gaseous emissions. Particulates would be generated by drilling, blasting, rock removal and storage, batch concrete plant operation, surface grading and leveling, wind erosion, and vehicle travel on paved and unpaved roads. Gaseous air pollutant emissions would consist of carbon monoxide, *nitrogen oxides*, *sulfur oxides*, and hydrocarbons. These pollutants would be produced by diesel- and gasoline-powered construction equipment and motor vehicles and by diesel-powered drilling engines and electric generators.

Air quality measurements at the repository site and in the repository site vicinity (see Section 3.1.2) have shown that site characterization activities similar to those described above have had a very small impact on the concentration levels of PM_{10} and of gaseous pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone). This analysis assumed that site characterization activities are representative of preconstruction testing and performance confirmation activities. As described in Section 3.1.2, pollutant levels have been below applicable National Ambient Air Quality Standards. Based on this experience, DOE does not expect large impacts to air quality from preconstruction testing and performance confirmation activities.

4.1.2.2 Impacts to Air Quality from Construction

This section describes potential radiological and nonradiological air quality impacts during the initial construction of the Yucca Mountain Repository, which for analysis purposes would last 5 years, from 2005 to 2010. Activities during this phase would include subsurface excavation to prepare the repository for initial emplacement operations and construction of surface facilities at the North Portal Operations Area, South Portal Development Area, and ventilation shaft areas and associated access roads.

4.1.2.2.1 *Nonradiological Impacts to Air Quality from Construction*

During the initial construction, repository activities would result in emissions of air pollutants. Subsurface excavation would release dust (particulate matter) from the ventilation exhaust. The excavation of rock would generate dust in the drifts. The dust would be vented from the subsurface through the South Portal. Construction activities on the surface would result in the following air emissions:

- Fugitive dust from the placement and maintenance of excavated rock at a surface storage site

- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, etc.) and particulate matter from the operation of construction vehicles
- Gaseous criteria pollutants and particulate matter from a diesel-fueled boiler at the North Portal Operations Area
- Particulate matter from a concrete batch plant at the North Portal Operations Area
- Fugitive dust from land-disturbing activities on the surface during construction activities

Table 4-1 lists the maximum estimated impacts to air quality at the boundary of the land withdrawal area used for purposes of analysis in this EIS. As listed in this table, maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small. Criteria pollutant concentrations would be less than 2 percent of the applicable regulatory limits for all operating modes with the exception of PM_{10}. The 24-hour PM_{10} concentrations for the range of operating modes would be about 4 to 6 percent of the regulatory limit. In addition, DOE expects levels of $PM_{2.5}$ to be well below the applicable standard because a large fraction of the particulates for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not have a major effect on concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

Table 4-1. Maximum construction phase concentrations of criteria pollutants and cristobalite at the land withdrawal area boundary (micrograms per cubic meter).[a]

			Operating mode			
			Maximum concentration[c]		Percent of regulatory limit	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.40	0.41 - 0.42	0.41	0.41 - 0.42
Sulfur dioxide	Annual	80	0.10	0.10	0.13	0.13
	24-hour	365	1.3	1.3	0.36	0.36
	3-hour	1,300	8.5	8.6 - 8.7	0.66	0.66 - 0.67
Carbon monoxide	8-hour	10,000	4.2	4.3 - 4.4	0.041	0.042 - 0.043
	1-hour	40,000	29	29 - 30	0.072	0.073 - 0.075
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.69	0.74 - 0.94	1.4	1.5 - 1.9
	24-hour	150 (65)	6.5	7.0 - 8.4	4.3	4.7 - 5.6
Cristobalite	[Annual[d]]	[10[d]]	0.018	0.017 - 0.018	0.18	0.17 - 0.18

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Table 3-5).
c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.
d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

Emissions of nitrogen dioxide, sulfur dioxide, and carbon monoxide would not be greatly different under the higher- and lower-temperature operating modes during the construction phase. Differences do result for PM_{10} releases during the larger land disturbances and maintenance of the larger excavated rock piles of the lower-temperature operating modes. The construction of ventilation shafts and their access roads contributes significantly to the particulate releases. Although well within regulatory limits, particulate release rates would be further reduced by dust suppression measures taken during construction.

Cristobalite is one of several naturally occurring crystalline forms of silica (silicon dioxide) that occur in Yucca Mountain tuffs. Cristobalite is principally a concern for involved workers who could inhale it during subsurface excavation operations (see Section 4.1.7). Prolonged high exposure to crystalline silica might cause silicosis, a disease characterized by scarring of lung tissue. Research has shown an increased cancer risk to humans who already have developed adverse noncancer effects from silicosis, but the cancer risk to otherwise healthy individuals is not clear (DIRS 103243-EPA 1996, p. 1-5). The evaluation of exposure to cristobalite encompassed potential impacts from exposure to other forms of crystalline silica, including quartz and tridymite, that occur at Yucca Mountain. See Appendix F, Section F.1.2, for more information.

Cristobalite would be emitted from the subsurface in exhaust ventilation air during excavation operations and would be released as fugitive dust from the excavated rock pile, so members of the public and noninvolved workers could be exposed. Fugitive dust from the excavated rock pile would be the largest potential source of cristobalite exposure to the public. The analysis assumed that 28 percent of the fugitive dust released from this pile and from subsurface excavation would be cristobalite, reflecting the cristobalite content of the parent rock, which ranges from 18 to 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81). Using the parent rock percentage probably overestimates the airborne cristobalite concentration because studies of both ambient and occupational airborne crystalline silica have shown that most is coarse and not respirable, and that larger particles rapidly deposit on the surface (DIRS 103243-EPA 1996, p. 3-26). Table 4-1 lists estimated cristobalite concentrations at the analyzed land withdrawal area boundary during the construction phase.

There are no regulatory limits for public exposure to cristobalite. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Over a 70-year lifetime, this cumulative exposure benchmark would correspond to an annual average exposure concentration of about 14 micrograms per cubic meter. For added conservatism, this analysis used an annual concentration of 10 micrograms per cubic meter as the benchmark for comparison. The postulated annual average exposure of the hypothetical maximally exposed member of the public to cristobalite from construction activities would be small, about 0.02 microgram per cubic meter or less for the various operating modes, or less than 0.2 (0.11) percent of the benchmark. DOE would use common dust suppression techniques (water spraying, etc.) to further reduce releases of fugitive dust, and hence cristobalite, from the excavated rock pile.

4.1.2.2.2 *Radiological Impacts to Air Quality from Construction*

No releases of manmade radionuclides would occur during the construction phase because such materials would not be present until the repository began operations. However, the air exhausted from the subsurface would contain naturally occurring radon-222 and its radioactive decay products. (Further references to radon in this discussion include its radioactive decay products.) Radon-222 is a noble gas and decay product of uranium-238 that occurs naturally in the rock. Exposure to radon-222 is ubiquitous (that is, it occurs everywhere). As described in Chapter 3, Section 3.1.8, exposure to naturally occurring radon-222 results in an annual average individual dose in the United States of about 200 millirem. In the subsurface, radon-222 would leave the rock and enter the drifts, a process called radon emanation. Once in the repository drifts the radon and decay products would be exhausted as part of repository ventilation. DOE based potential future releases of radon-222 on modeled estimates of radon flux, concentration, and release in the repository (DIRS 154176-CRWMS M&O 2000, all). These estimates were generated using observed radon concentrations in the Exploratory Studies Facility (DIRS 150246-CRWMS M&O 2000, Attachment X) and considering the repository structure and ventilation characteristics, particularly the ventilation pressure differentials. Total estimated radon releases during the 5-year construction phase would be very similar for the range of repository operating modes. These releases, and the potential doses that resulted from them, would be similar because the size and structure of the excavated repository

Main Index Vol 1 Index

and the repository ventilation would be similar under each mode during the construction phase. Appendix G, Section G.2, describes the methods, procedures, and basis of analysis.

The dose to the offsite maximally exposed individual, at the southern boundary of the land withdrawal area, would be about 1.7 to 2.0 millirem for the 5-year initial construction phase under the flexible design repository operating modes. The maximum annual dose to the offsite maximally exposed individual would be no more than about 0.53 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 3.5 percent of this standard. The offsite population dose would be 33 to 40 person-rem. The maximum annual dose to the maximally exposed noninvolved repository worker would be about 1.9 to 2.3 millirem during the initial construction phase. The analysis assumed that this worker, while at the site, would be in an office about 100 meters (330 feet) from the South Portal. The noninvolved worker population exposed to radon-222 from exhaust ventilation would include all the repository workers on the surface. Workers at the South Portal Development Area, who would be near the ground-level releases of radon from this portal, would receive most of the population dose. The dose to the noninvolved worker population from the air *pathway* would be less than 0.5 (0.48) person-rem during this phase (see Appendix G, Section G.2).

Table 4-2 lists estimated annual and 5-year construction phase doses from radon-222 for the maximally exposed individuals (both public and noninvolved surface worker) and potentially affected populations from the air pathway. Section 4.1.7 discusses potential human health impacts from these doses.

Table 4-2. Radiation doses to maximally exposed individuals and populations during initial construction phase.[a,b]

Impact	Operating mode: Higher-temperature Total	Higher-temperature Maximum annual	Lower-temperature Total	Lower-temperature Maximum annual
Dose to public				
Offsite MEI[c] (millirem)	1.7	0.43	1.7 - 2.0	0.43 - 0.53
80-kilometer population[d] (person-rem)	33	8.4	33 - 40	8.4 - 10
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[e] (millirem)	7.5	2.0	7.5 - 9.0	1.9 - 2.3
Yucca Mountain noninvolved worker population[f] (person-rem)	0.41	0.10	0.41 - 0.48	0.10 - 0.13
Nevada Test Site noninvolved worker population[g] (person-rem)	0.0013	0.00032	0.0013 - 0.0015	0.00032 - 0.00039

a. Numbers are rounded to two significant figures.
b. Annual values are for the maximum year during the construction phase.
c. MEI = maximally exposed individual; public MEI location would be at the southern boundary of the land withdrawal area.
d. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
e. The maximally exposed noninvolved worker location would be in the South Portal Development Area.
f. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
g. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.3 Impacts to Air Quality from Operation and Monitoring

This section describes potential nonradiological and radiological air quality impacts from routine operation and monitoring at the Yucca Mountain Repository. For analysis purposes, this phase would begin in 2010 for both repository operating modes; it would last for 100 years for the higher-temperature operating mode and from 149 to 324 years for the lower-temperature operating mode. Activities during this phase would include the continued excavation of subsurface drifts (beginning in 2010 and lasting 22 years), the receipt and packaging (handling) of spent nuclear fuel and high-level radioactive waste at the North Portal surface facilities (beginning in 2010 and lasting 24 years), and the emplacement of disposal containers in the repository (beginning in 2010 and lasting 24 years without aging or 50 years with aging). These activities would take place concurrently. After the emplacement of all spent nuclear fuel, monitoring of the disposal containers and maintenance of repository facilities would last from 76 to 300 years.

4.1.2.3.1 *Nonradiological Impacts to Air Quality from Operation and Monitoring*

DOE evaluated nonradiological air quality impacts from activities beginning at 2010, when handling and continued subsurface development and emplacement activities would occur simultaneously. This phase could last from 100 to 324 years, depending on the operating mode and design. Continued development of the subsurface facilities would last 22 years for all operating modes. Continued subsurface development would result in the release of dust (particulate matter) from the ventilation exhaust (at the South Portal). Activities on the surface would result in the following air emissions during this period:

- Fugitive dust emissions from the excavation, placement, and maintenance of rock at a surface storage pile
- Fugitive dust emissions from continued construction of the aging pads, if used to achieve lower-temperature operations
- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide) and particulate matter from vehicle operation during construction and emplacement
- Gaseous criteria pollutants and particulate matter from diesel-fed boilers at the North Portal Operations Area
- Particulate matter from a concrete batch plant at the North Portal Operations Area
- Cristobalite emissions from subsurface excavations and the excavated rock storage pile

The level of emissions would vary among the operating modes. The lower-temperature operating mode would result in larger excavated rock piles on the surface, which in turn would result in larger fugitive dust emissions and necessitate larger vehicle fleets for operation and maintenance.

Table 4-3 lists estimated maximum concentrations at the land withdrawal area boundary for the higher- and lower-temperature operating modes.

As listed in Table 4-3, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be very small. For the range of operating modes, the public maximally exposed individual would be exposed to less than 2 (1.6) percent of the applicable regulatory limits. In addition, levels of $PM_{2.5}$ should be well below the applicable standard because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. The concentrations of $PM_{2.5}$ would not be as affected by these suppression measures because fugitive dust is not a major source of $PM_{2.5}$.

Table 4-3 also lists cristobalite concentrations at the land withdrawal area boundary. As discussed for the initial construction phase (see Section 4.1.2.2.1), the analysis of the continuing construction, operation, and monitoring period assumed that 28 percent of the fugitive dust released from the excavated rock pile would be cristobalite. There are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The

Table 4-3. Maximum criteria pollutant and cristobalite concentrations at the land withdrawal area boundary during the operation and monitoring phase (micrograms per cubic meter).[a]

			Operating mode			
			Maximum concentration[c]		Percent of regulatory limit	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.28	0.28 - 0.31	0.28	0.29 - 0.32
Sulfur dioxide	Annual	80	0.089	0.089 - 0.092	0.11	0.11 - 0.12
	24-hour	365	1.2	1.2	0.33	0.34
	3-hour	1,300	7.8	7.9 - 8.0	0.60	0.61 - 0.62
Carbon monoxide	8-hour	10,000	2.7	2.7 - 3.0	0.026	0.027 - 0.029
	1-hour	40,000	19	19 - 21	0.048	0.049 - 0.052
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.080	0.10 - 0.19	0.16	0.20 - 0.39
	24-hour	150 (65)	0.97	1.3 - 2.3	0.65	0.87 - 1.6
Cristobalite	Annual[d]	10[d]	0.0093	0.009 - 0.017	0.093	0.091 - 0.17

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).
c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.
d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

estimated exposures to cristobalite from repository operations would be small, about 0.017 microgram per cubic meter or less for the range of operating modes, or less than 0.2 (0.11) percent of the benchmark.

Concentrations would differ between the construction phase and the emplacement and development activities. The rate of fugitive dust release and the subsequent PM_{10} concentrations would be higher during the construction phase than during emplacement and development activities because of the differing amount of land surface disturbance. Concentrations of cristobalite would be comparable in the construction and operation and monitoring phases. Concentrations of gaseous criteria pollutants would decrease during emplacement and development activities because vehicle emissions would decrease during emplacement and development. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions among the operating modes.

After the completion of emplacement activities, DOE would continue monitoring and maintenance activities lasting 76 to 300 years at the repository until closure. During this period, air pollutant emissions would decrease. Subsurface excavation and handling activities would be complete, resulting in a lower level of emissions. Pollutant concentrations at the land withdrawal area boundary, therefore, would be lower than those listed in Table 4-3.

The flexible design repository operating modes would remove at least 70 percent of the heat generated by the spent nuclear fuel inventory during the preclosure period (DIRS 153849-DOE 2001, p. 2-15). The peak ventilation air temperature for the higher-temperature operating mode would be 58ºC (136ºF) for 1.4-kilowatt-per-meter linear thermal load, occurring 10 years into the preclosure period and decreasing thereafter (DIRS 150941-CRWMS M&O 2000, pp. 4-24 to 4-25). The higher-temperature operating mode has the highest linear thermal load (DIRS 153849-DOE 2001, p. 2-24) and would have the highest exhaust air temperatures. This air temperature would be lower than the exhaust air temperature of many other industrial processes such as powerplants, manufacturing facilities, and incinerators. Impacts from the heat released in ventilation air would be unlikely on either the climate or ecosystems of the area.

4.1.2.3.2 *Radiological Impacts to Air Quality from Operation and Monitoring*

The handling of spent nuclear fuel and continued subsurface ventilation would result in radionuclide releases during the early years of the operation and monitoring phase. Radionuclides would be released during transfer of fuel assemblies from transportation casks to disposal containers. Releases of naturally occurring radon-222 from subsurface ventilation would continue. If surface aging was used, the initial 24 years of operations would be followed by 26 years of emplacing commercial spent nuclear fuel from the aging facility. Aging would result in a 50-year operations period rather than the 24-year period without aging.

After the completion of handling and emplacement operations, DOE would continue monitoring repository facility maintenance activities for 76 to 300 years. During this period, the Department would continue to ventilate the subsurface. Releases of naturally occurring radon-222 from subsurface ventilation would continue.

Operations Period. The main radionuclide released to the atmosphere from the handling of spent nuclear fuel assemblies in the Waste Handling Building would be krypton-85, a radioactive noble gas (DIRS 101893-NRC 1979, p. 4-10). Approximately 2,600 curies would be released annually (DIRS 152010-CRWMS M&O 2000, p. 52). Releases of other noble gas radionuclides would be very small. Estimated annual releases would be about 1.0×10^{-6} curie of krypton-81, 3.3×10^{-5} curie of radon-219, 5.9×10^{-2} curie of radon-220, and 4.6×10^{-6} curie of radon-222 (DIRS 152010-CRWMS M&O 2000, p. 52). Releases of these radionuclides, which are noble gases, would not be affected by facility filtration systems. No releases of particulate or soluble radionuclides would be likely. These radionuclides would be captured in the water of the transfer pool or the Waste Handling Building air filtration system.

A continuing source of dose to members of the public and noninvolved (surface) workers would be releases of naturally occurring radon-222 from the subsurface. Estimated radon emissions during the continuing construction, operation, and monitoring period would be greater than those during the initial construction period because of the larger repository size, with more surface area for radon flux from the repository walls and greater quantities exhausted by ventilation. The effect of waste packages heating the walls of the emplacement drifts, which would slightly increase the radon flux, was also considered (DIRS 154176-CRWMS M&O 2000, p. 10). The estimated differences in radon releases would be a function primarily of the waste package spacing, which would affect the total repository size, and of the duration of the monitoring period. In general, a larger waste package spacing distance would lead to a larger repository, which would result in more radon released per year and a shorter ventilation period. Annual releases, therefore, would be higher but total releases would be lower. Appendix G, Section G.2.3.1, contains more information on estimates of radon release for the range of operating modes. Activation of the air around waste packages would result in the creation of a small quantity of radioactive noble gases. These noble gases would contribute negligibly to the dose from the air pathway (DIRS 139546-CRWMS M&O 2000, all).

Table 4-4 lists estimated annual doses and doses during the handling and emplacement period to the maximally exposed individuals (public and noninvolved worker) and potentially affected populations from radionuclide releases from surface and subsurface facilities. As for the other project phases, naturally occurring radon-222 and its decay products released in subsurface ventilation air would be the major dose contributors from airborne releases. Krypton-85 and the other noble gas radionuclides released from the surface facilities would be a small component of the overall dose, contributing less than 0.01 percent of the dose to the public and typically less than 1 percent of the dose to noninvolved workers for the operations period. The principal exception would be the dose to the noninvolved worker population at the Nevada Test Site, where the krypton-85 contribution to dose would be as high as 3.5 percent of the total dose. Appendix G, Section G.2.3.2, discusses the methods for calculating the doses, and Section 4.1.7 discusses potential human health impacts from these doses.

Main Index Vol 1 Index

Table 4-4. Radiation doses for maximally exposed individuals and populations during the operations period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	Total	Maximum annual[c]	Total	Maximum annual[c]
Dose to public				
Offsite MEI[d] (millirem)	12	0.73	17 - 43	1.0 - 1.3
80-kilometer population[e] (person-rem)	230	14	320 - 830	20 - 26
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[f] (millirem)	30	2.0	39 - 42	2.8 - 3.0
Yucca Mountain noninvolved worker population[g] (person-rem)	1.2	0.081	1.8 - 1.9	0.12 - 0.13
Nevada Test Site noninvolved worker population[h] (person-rem)	0.011	0.00063	0.015 - 0.043	0.00090 - 0.0012

a. Numbers are rounded to two significant figures.
b. Fuel handling activities would last 24 years. Emplacement activities would last 24 years with no aging or 50 years with aging. Continuing subsurface development activities would last 22 years.
c. Maximum annual dose would occur during the last year of development, when the repository had reached its largest and DOE still used the South Portal for exhaust ventilation.
d. MEI = maximally exposed individual located at the southern boundary of the land withdrawal area.
e. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
f. Maximally exposed noninvolved worker location would be in the South Portal Development Area.
g. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
h. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

The dose to the offsite maximally exposed individual would be 12 to 20 millirem during the 24 years of operations, increasing to 43 millirem for the additional 26 years of operations if DOE used aging. The maximum annual dose to the offsite maximally exposed individual would be about 0.73 to 1.3 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 5 to 9 percent of this standard. The population dose would be 230 to 390 person-rem for 24 years of operations, increasing to 830 person-rem for the additional 26 years of operations with aging. Essentially the entire dose would be from naturally occurring radon-222 released from the subsurface in ventilation air. Releases of radioactive noble gases from surface facilities (Waste Handling and Waste Treatment Buildings) during spent nuclear fuel handling would make very small differences in the dose received. Aging would increase the operations period by 26 years, but also would decrease the monitoring period by 26 years, so the total impact would be unchanged.

The dose to the maximally exposed noninvolved (surface) worker in an office about 100 meters (330 feet) from the South Portal would be about 30 to 42 millirem during the 24 years of handling and emplacement activities, increasing less than 0.2 millirem for the additional 26 years of operations for aging. The increase would be small because DOE would stop using the South Portal for exhaust ventilation at the completion of development, and exhaust from the ventilation shafts would result in much less dose to the maximally exposed worker. The dose to the noninvolved worker population would vary in proportion to (1) the amount of radon-222 released from the subsurface, because radon-222 would dominate the radiation doses, and (2) the number of noninvolved (surface) workers. At the North Portal Operations Area, there would be about 1,300 workers annually (a total of 31,000 to 32,000 worker-years for 24 years of operations). This total would increase to about 50,000 surface worker-years for the 50 years of operations needed for aging. In addition, an estimated 1,500 to 2,100 total subsurface worker-years would be needed on the surface at the South Portal Development Area (see Appendix G, Table G-49). The noninvolved worker population dose would range from 1.2 to 1.8 person-rem over the 24-year emplacement period, increasing slightly to 1.9 person-rem considering the additional 26 years of the operations period needed for aging. Workers at the South Portal Development Area, who would be near the ground-level releases of radon from this portal during development activities, would receive most of the population dose from airborne releases. However, the bulk of worker radiation dose comes not from airborne releases but from more direct occupational exposure. Section 4.1.7 discusses impacts to workers directly involved in handling, emplacement, and continuing development activities.

Monitoring Period. Monitoring would continue and maintenance would begin immediately after the completion of emplacement activities. One of the first activities would be the decontamination of the surface material handling facilities. This activity, which would last 3 years, would require a larger number of noninvolved workers. These workers would be exposed to naturally occurring radon ventilated from the subsurface. Decontamination of the surface facilities would result in no or negligible airborne releases of radionuclides because of the low levels of contamination present, high-efficiency particulate air filters on the air exhausts, and modern facility design and decontamination techniques that would minimize the potential for airborne contamination. After the completion of decontamination, most of the noninvolved workers would no longer be employed, resulting in a much lower noninvolved worker population and correspondingly lower worker population dose.

Monitoring periods would range from 76 to 300 years depending on the repository operating mode and selected operating parameters. Table 4-5 lists estimated maximum annual doses and total doses that would occur from monitoring and maintenance activities to maximally exposed individuals and potentially affected populations from subsurface radon releases. Section 4.1.7 discusses potential radiological impacts from these doses. The dose over the 70-year lifetime of the hypothetical offsite maximally exposed individual, at the southern boundary of the land withdrawal area, would be 29 to 62 millirem during monitoring and maintenance activities for the range of repository operating modes. The maximum annual dose to the offsite maximally exposed individual would be about 0.41 to 0.89 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 3 to 6 percent of this standard. The hypothetical offsite maximally exposed individual would receive a higher dose than the noninvolved worker maximally exposed individual because air would be removed from the repository through exhaust shafts, which would result in more radon being carried to the exposure point for the offsite individual than to that for the noninvolved worker.

The population dose for monitoring and maintenance activities would range from 600 to 3,500 person-rem, the difference mainly reflecting the range of 76 to 300 years of postemplacement monitoring. The dose to the maximally exposed noninvolved (surface) worker, who would be at the South Portal Development Area, would range from 0.096 to 0.33 millirem for a 50-year working lifetime during monitoring and maintenance activities. The dose to the repository noninvolved (surface) worker population, which would include all surface workers (most of whom would be at the North Portal Operations Area), would range from 0.0091 to 0.05 person-rem for the monitoring period.

In general, longer periods of monitoring and maintenance activities would result in larger total releases of radon and its decay products and potentially extend these impacts to future generations of workers and the public. Highest total doses during the monitoring period for the 80-kilometer (50-mile) population and the Nevada Test Site noninvolved worker population would be under conditions of maximum ventilation and moderate waste package spacing, which would require the longest time (300 years) of ventilation and monitoring. For the other potential doses listed in Table 4-5, the highest potential total and annual doses for monitoring would be under conditions of largest waste package spacing, which would require the largest repository and have the largest radon release per year from the repository. Section 4.1.7 discusses human health impacts to the public and workers from the monitoring period.

Main Index Vol 1 Index

Table 4-5. Radiation doses to maximally exposed individuals and populations during the monitoring period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	Total	Maximum annual	Total	Maximum annual
Dose to public				
Offsite MEI[c] (millirem)	29	0.41	30 - 62	0.59 - 0.89
80-kilometer population[d] (person-rem)	600	8	1,500 - 3,500	11 - 17
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[e] (millirem)	0.096	0.0019	0.16 - 0.33	0.0011 - 0.0067
Yucca Mountain noninvolved worker population (person-rem)	0.0091	0.0013[f]	0.031 - 0.05	0.000034 - 0.0057[f]
Nevada Test Site noninvolved worker population[g] (person-rem)	0.033	0.00044	0.083 - 0.19	0.00021 - 0.00094

a. Numbers are rounded to two significant figures.
b. Decontamination of surface facilities during the operation and monitoring phase would last 3 years at the beginning of monitoring, which would last from 76 to 300 years.
c. MEI = maximally exposed individual located at the southern boundary of the land withdrawal area. Values are for a 70-year lifetime.
d. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Development Area. Values are for a 50-year onsite working lifetime.
f. Maximum annual dose occurs during the 3 years of decontamination activities when worker population is largest.
g. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.4 Impacts to Air Quality from Closure

This section describes potential nonradiological and radiological air quality impacts during the closure phase of the proposed Yucca Mountain Repository, which would begin after the 76 to 300 years of monitoring and last 10 to 17 years. Activities during this phase would include the closure of subsurface repository facilities, the decommissioning of surface facilities, and the reclamation of remaining disturbed lands.

4.1.2.4.1 *Nonradiological Impacts to Air Quality from Closure*

During the closure phase, nonradiological air emissions would result from the backfilling and sealing of the repository subsurface and the reclamation of disturbed surface lands. Air emission sources would include the following:

- Fugitive dust emissions from the handling, processing, and transfer of backfill material to the subsurface
- Releases of gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, and carbon monoxide) and particulate matter from fuel consumption
- Gaseous criteria pollutants and particulate matter from diesel-fed boilers at the North Portal Operations Area
- Particulate matter from a concrete batch plant at the North Portal Operations Area
- Fugitive dust releases from demolishing buildings, removing debris, and reclaiming land

- Cristobalite releases associated with handling and storing excavated rock

Table 4-6 lists potential impacts at the location of the offsite maximally exposed individual from the closure of the repository for the higher- and lower-temperature operating modes.

Table 4-6. Maximum criteria pollutant and cristobalite concentrations at the land withdrawal area boundary during closure phase (micrograms per cubic meter).[a]

			Operating mode			
			Maximum concentration[c]		Percent of regulatory limit	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.54	0.54	0.54	0.54 - 0.55
Sulfur dioxide	Annual	80	0.11	0.11	0.15	0.15
	24-hour	365	1.4	1.4	0.38	0.38
	3-hour	1,300	9.3	9.3	0.71	0.71 - 0.72
Carbon monoxide	8-hour	10,000	4.7	4.7	0.045	0.045 - 0.046
	1-hour	40,000	31	31	0.078	0.078
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.38	0.34 - 0.37	0.76	0.67 - 0.73
	24-hour	150 (65)	5.5	5.2 - 5.4	3.7	3.4 - 3.6
Cristobalite	Annual[d]	10[d]	0.012	0.0089 - 0.0098	0.12	0.089 - 0.098

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).
c. Sum of the highest concentrations at the accessible land withdrawal boundary regardless of direction.
d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

Gaseous criteria pollutants would result primarily from vehicle exhaust. During the closure phase, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small, with the gaseous criteria pollutant concentrations being less than 1 percent of the applicable regulatory limits. The 24-hour PM_{10} concentrations would be about 4 percent of the regulatory limit for all operating modes. Levels of $PM_{2.5}$ should also be well below the applicable standard, because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not affect the concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

As discussed for the construction phase (see Section 4.1.2.2.1), the analysis of the closure phase assumed that 28 percent of the fugitive dust released from the excavated rock pile would be cristobalite. Table 4-6 lists estimated cristobalite concentrations to which the offsite maximally exposed individual would be exposed during closure. As noted in Section 4.1.2.2.1, there are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The postulated exposure to cristobalite from closure activities would be small, about 0.01 microgram per cubic meter or less for all three thermal load scenarios, or less than one-tenth of 1 percent (0.098) of the benchmark. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions among the operating modes.

4.1.2.4.2 *Radiological Impacts to Air Quality from Closure*

During the closure phase the only doses from releases of radionuclides to the atmosphere would be from naturally occurring radon-222 and its radioactive decay products released from the continued ventilation of subsurface facilities. The analysis assumed that subsurface ventilation would continue for the duration of the closure phase, lasting 10 to 17 years. Exposure to the noninvolved (surface) worker population would occur during the 6-year period while this group was working on surface facility closure. Exposure would continue to members of the public and a smaller number of workers throughout the period for subsurface facility closure.

Table 4-7 lists estimated annual doses and total doses from radon-222 during the closure phase to maximally exposed individuals and potentially affected populations from radionuclide releases from subsurface facilities. Section 4.1.7 discusses potential radiological impacts from these doses. The total dose to the offsite maximally exposed individual would be 3 to 9.4 millirem for the closure phase. The maximum annual dose to the offsite maximally exposed individual would be about 0.4 to 0.87 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 3 to 6 percent of this standard. The population dose would be 57 to 180 person-rem for the closure phase. The dose to the maximally exposed noninvolved (surface) worker at the South Portal would be 0.014 to 0.07 millirem for the entire closure phase. The dose to the noninvolved repository (surface) worker population would range from 0.004 to 0.015 person-rem. Highest doses for this phase—both total and annual—would be under conditions of largest waste package spacing, which would require the largest repository and the longest time (17 years) to close the repository.

Table 4-7. Radiation doses to maximally exposed individuals and populations from radon-222 releases from the subsurface during closure phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	Total	Maximum annual[c]	Total	Maximum annual[c]
Dose to public				
MEI[c] (millirem)	3	0.4	4.3 - 9.4	0.57 - 0.87
80-kilometer population[d] (person-rem)	57	7.4	83 - 180	10 - 16
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[e] (millirem)	0.014	0.0018	0.024 - 0.07	0.003 - 0.0063
Yucca Mountain noninvolved worker population (person-rem)	0.004	0.00052	0.007 - 0.015	0.00088 - 0.0014
Nevada Test Site noninvolved worker population[f] (person-rem)	0.0031	0.00041	0.0046 - 0.0099	0.00058 - 0.00089

a. Numbers are rounded to two significant figures.
b. The closure phase would begin after the 76 to 300 years of monitoring and last 10 to 17 years.
c. MEI = maximally exposed individual located at the southern boundary of the land withdrawal area.
d. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Development Area.
f. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.5 Total Impacts to Air Quality from All Phases

The nonradiological air quality analysis examined concentrations of criteria pollutants in comparison to National Ambient Air Quality Standards. These standards are for periods ranging from 1 hour up to an annual average concentration of pollutant, so a "total" project impact is presented as no more than the highest single year. The highest concentrations of all criteria pollutants except PM_{10} would be less than 1 percent of applicable standards in all cases. PM_{10} would also be less than 1 percent of the applicable limits except: it would be less than 2 percent of the annual limit and 6 percent of the 24-hour limit during the construction phase; less than 2 percent of the 24-hour limit during the operation and monitoring phase; and less than 4 percent of the 24-hour limit during the closure phase.

The radiological impacts to air quality for the entire project are quantified by evaluating the doses to the populations of potentially exposed workers and members of the public. Results are not presented for impacts to individuals because the project duration (from 115 to 341 years) would be longer than the 70-year lifetime used for analysis purposes. Individual impacts for the various project activity periods (as long as 50 years for workers and 70 years for the public for the longer monitoring period) are discussed in the previous sections.

Table 4-8 lists total radiological air quality impacts for the entire Yucca Mountain Repository project. This table includes impacts for the higher-temperature repository operating mode and the range of impacts for the lower-temperature operating mode. The higher-temperature operating mode would have lower radiological air quality impacts, because it would have the shortest project duration (115 years), smallest excavated repository volume and therefore lowest releases of naturally occurring radon-222 and decay products, the primary dose contributor.

Table 4-8. Total radiation doses to exposed individuals and populations for all phases.[a,b,c]

	Operating mode			
	Higher-temperature		Lower-temperature[d]	
Release	Entire project	Annual	Entire project	Annual
Dose to public				
MEI[e] (millirem)	31	0.73	44 - 62	1 - 1.3
80-kilometer population[f] (person-rem)	930	14	1,900 - 3,900	20 - 26
Dose to noninvolved workers (person-rem)				
Maximally exposed noninvolved worker[e] (millirem)	30	2	39 - 42	2.8 - 3.0
Yucca Mountain noninvolved worker[g] population	1.7	0.1	1.7 - 2.4	0.12 - 0.13
Nevada Test Site noninvolved worker population[h]	0.048	0.00063	0.1 - 0.21	0.0009 - 0.0012

a. Numbers are rounded to two significant figures.
b. The duration of all project phases (construction, operation and monitoring, and closure) would range from 115 to 341 years.
c. Section 4.1.7.5.3 describes radiological health impacts.
d. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
e. MEI = maximally exposed individual. The public MEI would be exposed 70 years and the noninvolved worker MEI exposed 50 years.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
g. For air quality impacts, noninvolved workers include those at the repository surface who could be exposed to releases of radon-222 and its decay products from the exhaust shafts.
h. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.3 IMPACTS TO HYDROLOGY

The following sections describe environmental impacts to the hydrology of the Yucca Mountain region, first from performance confirmation activities (Section 4.1.3.1), then from construction, operation and monitoring, and closure actions. The latter actions are presented in terms of surface water (Section 4.1.3.2) and groundwater (Section 4.1.3.3). Chapter 5 discusses long-term postclosure impacts resulting from repository performance.

The analysis evaluated surface-water and groundwater impacts separately. The attributes used to assess surface-water impacts were the potential for introduction and movement of contaminants, potential for changes to runoff and infiltration rates, alterations in natural drainage, and potential for flooding to aggravate or worsen any of these conditions. The region of influence for surface-water impacts included areas near construction and operation activities that would be susceptible to erosion, areas affected by permanent changes in flow, and downstream areas that would be affected by eroded soil or potential spills of contaminants. The analysis of surface-water impacts considered known perennial and intermittent lakes, surface streams, and washes.

The analysis assessed groundwater impacts to determine the potential for a change in infiltration rates that could affect groundwater, the potential for introduction of contaminants, the availability of groundwater for use during construction and operations, and the potential that such use would affect other users. The region of influence for this analysis included aquifers under the areas of construction and operations that DOE could use to obtain water and downstream aquifers that repository use or long-term releases from the repository could affect. The evaluation of groundwater impacts considered perennial yields of groundwater resources in comparison to known uses and requirements.

4.1.3.1 Impacts to Hydrology from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities would be unlikely to cause large impacts to the surface hydrology at the Yucca Mountain site, where there are no perennial streams or other permanent surface-water bodies. As during site characterization, DOE would design roads or other surface disturbances to minimize alterations to natural flowpaths and nearby washes (such as Drill Hole Wash). (See Section 4.1.4.2 and Chapter 11 for discussions of protection of waters of the United States.)

The preconstruction testing and performance confirmation studies would not adversely affect groundwater quality because DOE would use only limited quantities and types of hazardous materials, and activities involving such materials would be in strict accordance with applicable regulations and DOE Orders. State and Federal environmental, health, and safety regulations, as well as its own internal rules would require DOE to manage hazardous materials carefully and to clean up and report any measurable spills or releases promptly. Thus, the control of hazardous materials would be such that the potential for groundwater contamination would be very low.

DOE would use existing groundwater wells to support performance confirmation activities (for example, wells J-12 and J-13). In addition, it could use the existing C-well complex for aquifer testing and for a backup water supply. The Department expects water use from wells J-12 and J-13 to be similar to or less than that experienced during site characterization, which averaged about 0.093 million cubic meters (75 acre-feet) a year from 1993 through 1997 (not including test pumping at the C-well complex) (see Table 3-16). This would equal approximately 2 to 9 percent of the estimated perennial yield of the hydrographic basin (Jackass Flats) of 1.1 million to 4.9 million cubic meters (880 to 4,000 acre-feet) a year (see Table 3-11). Therefore, adverse effects on the quantity of groundwater resources would be unlikely. DOE could conduct pump tests of the aquifer at the C-well complex during performance confirmation activities. Under such tests, the amount pumped probably would be similar to that pumped during site characterization [about 0.23 million cubic meters (190 acre-feet) per year]. Even with this additional quantity, water demand would still be well below the lowest estimates of the basin's perennial yield, and DOE would manage water withdrawn from the C-well complex as part of aquifer testing in the same manner it has used for site characterization activities (that is, discharged to a spreading basin with State of Nevada concurrence and credit for groundwater recharge).

4.1.3.2 Impacts to Surface Water from Construction, Operation and Monitoring, and Closure

There are no perennial streams or other permanent surface-water bodies in the Yucca Mountain vicinity. The occurrence of natural surface water is limited to short periods when precipitation lasts long enough or is of high enough intensity to generate runoff to the natural drainage channels. In rare instances, runoff from the area of the proposed repository and support facilities could reach such channels as Drill Hole Wash, then flow to Fortymile Wash, and eventually reach the Amargosa River. Under most precipitation events, however, water simply soaks into the ground and is usually lost to evapotranspiration or, if there is enough to accumulate in drainage channels, soaks into the dry washes before traveling far, becoming potential recharge in these localized areas. Other potential sources of surface water associated with the

Proposed Action, such as the water used for dust suppression, would be a result of pumping groundwater to the surface.

The surface-water impacts of primary concern are related to the following:

- Introduction and movement of contaminants
- Changes to runoff or infiltration rates
- Alterations of natural drainage
- Impacts to floodplains

Discharges of Water to the Surface

During the 5-year initial construction phase, and during the operations period that would follow (lasting 24 years or 50 years if surface aging was used), sources of surface water other than precipitation would be limited primarily to the water DOE would use for dust suppression on the surface and below ground (with accumulations pumped back to the surface). Sanitary sewage, which would be piped to septic tank and drainage field systems, would not produce surface water. In addition, DOE would pump fresh water (groundwater) at the site and store it in tanks.

DOE has evaluated dust suppression actions during characterization efforts at the Yucca Mountain site for their potential to cause deep infiltration of water (DIRS 102547-CRWMS M&O 1997, pp. 51 to 53 and 73). The evaluation concluded that the amount of water actually used for dust suppression activities during site characterization has not caused water to penetrate the underlying rock. Studies at the site on infiltration capacities of natural soils (DIRS 100147-Flint, Hevesi, and Flint 1996, pp. 57 to 59) show that runoff or deep infiltration would not occur as a result of water applications for dust suppression. DOE would establish controls as necessary to ensure that water application for subsurface and surface dust control did not affect repository performance or result in large impacts.

Water would be pumped from the surface facilities to the subsurface during the construction phase and operations period while subsurface development continued. DOE would collect excess water from dust suppression applications and water percolating into the repository drifts, if any, and pump it to the surface, generating another source of surface water. Water pumped from the subsurface would go to an evaporation pond at the South Portal Development Area. The pond would be lined with heavy plastic to prevent infiltration or water loss. Table 4-9 lists discharge estimates to the South Portal evaporation pond for the higher- and lower-temperature operating modes. During the operations period, the quantity of water discharged would vary in proportion to the amount of subsurface excavation. Annual discharges under the lower-temperature operating mode would increase in comparison to those from the higher-temperature operating mode because of increased waste package spacing and the associated increase in drift excavation. DOE would investigate the feasibility of recycling all, or a portion, of this water.

The operation of heating and air conditioning systems at the North Portal Operations Area would result in the generation of wastewater (primarily from cooling tower blowdown and water softener regeneration) that DOE would discharge to the North Portal evaporation pond, which would be lined with heavy plastic. In addition, water collected from the emplacement side of the subsurface area, if any, would be pumped to this pond after verification that it was not contaminated. Table 4-10 lists the estimated discharges to the North Portal evaporation pond for the operating modes during the operations period. The estimates of annual discharge would change under the lower-temperature operating mode depending on the specific operating parameters used. These changes would be due primarily to a small change in the estimated size (total floor space) of the facilities.

The South Portal evaporation pond would be double-lined with polyvinyl chloride and would have a leak detection system (DIRS 102303-CRWMS M&O 1998, p. 16). The North Portal evaporation pond, which would be primarily for cooling and heating process water, would, at a minimum, have a polyvinyl

Main Index
Vol 1 Index

Table 4-9. Annual water discharges to South Portal evaporation pond.[a,b]

Phase	Operating mode	
	Higher-temperature[a,b]	Lower-temperature[a,c]
Construction		
Discharge (cubic meters)[d]	6,800	8,500 - 9,000
Duration (years)	5	5
Operations period		
Discharge (cubic meters)	3,500	4,400 - 7,500
Duration (years)	22[e]	22[e]

a. Estimated at 13 percent of the process water pumped to the subsurface based on Exploratory Studies Facility construction experience.
b. Source: DIRS 150941-CRWMS M&O (2000, pp. 6-7 and 6-12).
c. Source: DIRS 155515-Williams (2001, pp. 13 and 17; Parts 1 and 2, pp. 5 and 9).
d. To convert cubic meters to gallons, multiply by 264.18.
e. Discharge to this pond is during subsurface development activities only.

chloride liner (DIRS 102303-CRWMS M&O 1998, pp. 16 and 28). With proper maintenance, both ponds should remain intact and would have no effect on the site. DOE would build a third, much smaller evaporation pond, as appropriate, at the concrete batch plant to facilitate collection and management of equipment rinse water. Chapter 9 discusses mitigation measures associated with the Proposed Action.

Table 4-10. Annual water discharges to North Portal evaporation pond during operations period.

Factor	Operating mode	
	Higher-temperature[a]	Lower-temperature[a,b]
Discharge (cubic meters)[c]	34,000	31,000 - 36,000
Duration (years)	24	24

a. Source: DIRS 152010-CRWMS M&O (2000, p. 52).
b. Source: DIRS 155516-Williams (2001, p. 4)
c. To convert cubic meters to gallons, multiply by 264.18.

Other uses of water during the operations period would occur in the repository facilities and would have little, if any, potential to generate surface water. These sources include the washdown stations and the pools in the Waste Handling Building. Water from either of these sources would be managed as liquid low-level radioactive waste and treated in the Waste Treatment Building. Water from the treatment process would be recycled to the extent practicable, and residues and solids would be prepared for offsite shipment and disposal.

The quantity of water discharges to the surface during the monitoring period and from closure would be similar to or less than those discussed for the initial construction phase and operations period. The evaporation ponds would no longer be in use but other manmade sources of surface water should be very similar; water storage tanks would still be in use, there would be sanitary sewage, and dust suppression activities would occur.

Potential for Contaminant Spread to Surface Water

The potential for contaminants to reach surface water would generally be limited to the occurrence of a spill or leak followed by a rare precipitation or snow melt event large enough to generate runoff. DOE would design each facility that would contain radioactive material at the repository site such that flooding would not threaten material in the facility. Consistent with DOE Order 6430.1A*, General Design Criteria*, Nuclear Regulatory Commission licensing requirements, and national standards such as those of the American National Standards Institute, facilities in the Radiologically Controlled Area (for the management of radioactive materials) would be built to withstand the probable maximum flood. For example, if the footprint of a facility in the Radiologically Controlled Area was within the predicted natural inundation level of the probable maximum flood, one way to protect the facility would be to build up its foundation so it would be above the flood level and associated debris flows (DIRS 102303-CRWMS M&O 1998, pp. 32 to 37). Other facilities would be designed and built to withstand a 100-year flood, consistent with common industrial practice. Inundation levels expected from a 100-year, 500-year, regional maximum, or even probable maximum flood would represent no hazard to the proposed repository subsurface facilities, the portals of which would be at higher elevations than the flood-prone areas (DIRS 151945-CRWMS M&O 2000, p. 7.3-4 and Figure 7.3-3).

DOE would minimize the potential for a contaminant spread by managing spills and leaks in the proper and required manner. Activities at the site would adhere to a Spill Prevention, Control, and Countermeasures Plan [DIRS 104903-K/PB (1997, all) is an example] to comply with environmental regulations and to ensure best management practices. The plan would describe the actions DOE would take to prevent, control, and remediate spills. It would also describe the reporting requirements that would accompany the identification of a spill. As an additional measure to reduce the potential for contaminant release to surface water, DOE would build two stormwater retention basins near the North Portal Operations Area, one for the Radiologically Controlled Area and one for the balance-of-plant facilities. The basin for the Radiologically Controlled Area would contain the runoff from a storm consistent with the probable maximum flood. The basin for the balance-of-plant area would contain the runoff from a storm consistent with a 100-year flood.

The primary sources of potential surface-water contaminants during both the construction and the operation and monitoring phases would be the fuels (diesel and gasoline) and lubricants (oils and greases) needed for equipment. Fuel oil storage tanks would be in place relatively early in the construction phase. Each would be constructed with an appropriate containment structure (consistent with 40 CFR Part 112). Other organic materials such as paints, solvents, strippers, and concrete additives would be present during the construction phase but in smaller quantities and much smaller containers.

The operation and monitoring phase would involve the use of other chemicals, particularly in the Waste Treatment Building, where the liquid low-level radioactive waste treatment process, for example, would include the use of liquid sodium hydroxide and sulfuric acid. In addition, this phase would require relatively small quantities of cleaning solvents [up to about 1,300 liters (330 gallons) per year] (DIRS 152010-CRWMS M&O 2000, p. 51). Because these materials would be used and stored inside buildings and managed in accordance with applicable environmental, health, and safety standards and best management practices, there would be little potential for contamination to spread through contact with surface water.

In addition, liquid low-level radioactive waste present in the Radiologically Controlled Area would be treated in the Waste Treatment Building to stabilize such material with cement or grout before it left the facility. Similarly, hazardous waste and mixed waste would be maintained and moved in closed containers. These conditions would minimize the potential for spills and leaks that could lead to contaminant spread.

Radioactive materials present during the operation and monitoring phase would be managed in the Radiologically Controlled Area of the North Portal Operations Area. This would include the Carrier Parking Area and Carrier Preparation Building across Midway Valley Wash to the northeast, and the aging pads if used for the lower-temperature operating mode. The radiological materials would always be in containers or casks except when they were in the Waste Handling and Waste Treatment Buildings. In those buildings, facility system and component design would prevent inadvertent releases to the environment; drainlines would lead to internal tanks or catchments, air emissions would be filtered, fuel pools would have secondary containment and leak detection, and other features would have similar safety or control components. If a lower-temperature operating mode with surface aging was implemented, the fuel blending pools (total capacity of 5,000 MTHM) would be eliminated from the design. A fuel transfer pool associated with the assembly transfer system would still be present, but would represent a much smaller volume of water. Elimination of the blending pools would eliminate a source of potential water releases, but in all cases the probability of leakage from any of these pools would be very low, given current design engineering, and construction standards and the importance of leak prevention.

During the operation and monitoring phase a surface environmental monitoring system would monitor the surface areas and groundwater for radioactive and hazardous substance release (DIRS 101779-DOE 1998, Volume 2, p. 4-37). It would also monitor facility effluents and testing wells for the presence of radiological or other hazardous constituents that could indicate a release from an operation activity. The combination of minor sources of surface water and the prevention and control of contaminant releases would limit the potential for contaminant spread by surface water.

Monitoring and maintenance activities after the completion of emplacement would involve a decrease in general activities at the site and, accordingly, less potential for spills or releases to occur. Decontamination actions that would follow emplacement could present other risks, due to the possible presence of decontamination chemicals and the start of new work activities. DOE would continue to use controls, monitoring, response plans and procedures, and regulatory requirements to limit the potential for spills or releases to occur from these activities.

The potential for contaminant spread would be limited during the closure phase and would be reduced further during postclosure care of the site. As in the other phases, engineering controls, monitoring, and release response requirements would limit the potential for contaminants to reach surface water.

Potential for Changes to Surface Water Runoff or Infiltration Rates

Construction activities that disturbed the land surface would alter the rate at which water could infiltrate the disturbed areas. A maximum of about 2.8 square kilometers (690 acres) of land would be disturbed during the construction and operation and monitoring phases of the higher-temperature operating mode. Including land already disturbed during the characterization activities, the total would be about 4.3 square kilometers (1,060 acres). The amount of newly disturbed land would be about 4.0 to 4.5 square kilometers (990 to 1,100 acres) under the lower-temperature operating mode. Depending on the type of disturbance, the infiltration rate could increase (for example, in areas with loosened soil) or decrease (for example, in areas where construction activities had compacted the soil or involved the installation of relatively impermeable surfaces like asphalt pads, concrete surfaces, or buildings). Most of the land disturbance during construction would result in surfaces with lower infiltration rates; that is, the surfaces would be less permeable than natural soil conditions and would cause an increase in runoff. However, DOE expects the change in the amount of runoff actually reaching the drainage channels to be relatively minor, because repository construction would affect a relatively small amount of the natural drainage area. For example, almost all of the area that would be disturbed at the proposed repository site is drained by Drill Hole Wash, which includes Midway Valley Wash as a major tributary. The maximum new disturbance of 4.5 square kilometers (1,100 acres) would be small (less than 12 percent) in comparison to the approximate 40 square kilometers (9,900 acres) that comprise the drainage area of Drill Hole Wash by the time it reaches Fortymile Wash (DIRS 102783-Squires and Young 1984, p. 2).

Monitoring and maintenance activities would not disturb additional land and, therefore, would have no notable impacts to runoff rates in the area. Reclamation of previously disturbed land would restore preconstruction runoff rates.

DOE anticipates that closure activities would disturb only land that had been previously disturbed during earlier phases. The removal of structures and impermeable surfaces would decrease runoff from these areas and should put them in a condition closer to that of the surrounding natural surfaces. Reclamation efforts such as topsoil replacement and revegetation should help restore the disturbed areas to nearly natural conditions in relation to infiltration and runoff rates. The construction of monuments as long-lasting markers of the site use would be likely to make their locations impervious to infiltration but, as described above, change in runoff from the relatively small impervious areas would be small in comparison to the total drainage area.

Potential for Altering Natural Surface-Water Drainage

Construction activities can alter natural drainage systems if they (1) increase the erosion and sedimentation process (material eroded from one location in the drainage system is subsequently deposited in another location), or (2) place a structure, facility, or roadway in a drainage channel or flood zone. Section 4.1.4.4 discusses erosion issues. The focus of this section is the planned construction of structures, facilities, or roadways over natural drainage channels.

Pursuant to Executive Order 11988, *Floodplain Management*, each Federal agency is required, when conducting activities in a floodplain, to take action to reduce the risk of flood damage; minimize the impact of floods on human safety, health, and welfare; and restore and preserve the natural and beneficial values served by floodplains. DOE regulations implementing this Executive Order are at 10 CFR Part 1022.

Repository-related structures could affect small drainage channels or washes. DOE expects to control surface-water drainage in these washes with minor diversion channels, culverts, or similar drainage control measures. Some transportation-related construction, operation, and maintenance actions would occur in the floodplains of as many as four washes in the Yucca Mountain vicinity. Construction, operation, and maintenance of a rail line, roadways, and bridges in the Yucca Mountain vicinity could affect the 100- and 500-year floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash at Yucca Mountain. Appendix L contains a floodplain/wetlands assessment that describes in detail the actions that DOE could take. The analysis indicated that consequences of the actions DOE could take in or near the floodplains of these four washes would be minor and unlikely to increase the impacts of floods on human health and safety or harm the natural and beneficial values of the affected floodplains. It also indicated that there are no delineated wetlands at Yucca Mountain. The floodplains affected and the extent of activities in the floodplains would depend on the route DOE selected.

Closure of the repository should involve no actions that would alter natural drainage beyond those from the other phases. Areas where facilities were removed would be graded to match the natural topography to the extent practicable. Monuments would not be constructed in locations where they would alter important drainage channels or patterns and, in the process, back up or divert any meaningful volume of runoff.

4.1.3.3 Impacts to Groundwater from Construction, Operation and Monitoring, and Closure

This section identifies potential impacts to groundwater. Section 3.1.4 describes existing groundwater characteristics and uses in the Yucca Mountain vicinity. The potential impacts discussed in this section would be associated with the repository project, which would include construction, operation and monitoring, and closure. Chapter 5 describes potential impacts as a result of the repository's long-term performance after closure. The following impacts would be of primary concern while the repository was open:

- The potential for a change in infiltration rates that could increase the amount of water in the unsaturated zone and adversely affect the performance of waste containment in the repository, or decrease the amount of recharge to the aquifer
- The potential for contaminants to migrate to the unsaturated or saturated groundwater zones
- The potential for water demands associated with the repository to deplete groundwater resources to an extent that could affect downgradient groundwater use or users

This section discusses these potential impacts in general terms, primarily in relation to changes from existing conditions.

Infiltration Rate Changes

As discussed in Section 4.1.3.2, surface-disturbing construction activities would alter infiltration rates in the repository area. In the Yucca Mountain environment, water rarely travels long distances on the surface before infiltrating into the ground or evaporating. If construction activities resulted in disturbed land that was loose or broken up, local infiltration would increase and the amount of runoff reaching nearby drainage channels would decrease accordingly. Conversely, completed construction that involved either compacted soil or facility surfaces (concrete pads, asphalt surfaces, etc.) would result in less local infiltration and more water available to reach the drainage channels and then infiltrate into the ground. However, the location where infiltration takes place can have an effect on what happens to the water. That is, in some locations the water would be more likely to contribute to deep infiltration and possibly even to recharge to the aquifer.

In the semiarid environment in the Yucca Mountain vicinity, surface areas where meaningful recharge to the aquifer can occur are generally places such as Fortymile Wash (Section 3.1.4.2.2), which collects runoff from a large drainage area. Enough water can accumulate there to cause deep infiltration and occasional recharge. There is not enough precipitation or runoff in most other areas to generate infiltration deep enough to prevent its loss to evapotranspiration between precipitation events. In general, this will be the case even when land disturbance causes an increase in local infiltration. The most likely way that recharge could be affected would be for land disturbance to cause additional runoff (as from constructed facilities) that could accumulate in areas such as Fortymile Wash, and the effect would be a potential for increased recharge. However, given the dry climate and relatively small amount of potentially disturbed area in relation to the surrounding unchanged areas, the net change in infiltration would be small.

Surface disturbances could change infiltration rates in areas where the layer of unconsolidated material is thin and the disturbance resulted in the exposure of fractured bedrock. Cracks and crevices in the bedrock could provide relatively fast pathways for the movement of water to deep parts of the unsaturated zone (DIRS 151945-CRWMS M&O 2000, p. 8.9-8), where the water would be less susceptible to evapotranspiration. These effects would be applicable to the Emplacement and Development Shaft Operations Areas, which would be on steeper terrain, uphill from the South Portal Development Area and North Portal Operations Area, where the depth of unconsolidated material is likely to be thin. However, the amount of disturbed land would be small in comparison to the surrounding undisturbed area, and any net change in infiltration would be small.

Subsurface activities would have the potential to affect the amount of water in the unsaturated zone that could infiltrate more deeply, possibly even as recharge to the aquifer. These activities would include measures to minimize the quantities of standing or infiltrating water in the repository by pumping it to the surface for evaporation. Potential sources of this water could include water percolating in from the unsaturated zone and water pumped from the surface for underground dust control measures. The latter should involve the largest volume by far, much of which would be brought to the surface with the excavated rock generated by tunnel boring machines. Excess water in the subsurface would evaporate (the underground areas would be ventilated), be collected and pumped to the surface, or be lost as infiltration to cracks and crevices in the rock. During excavation of the Exploratory Studies Facility, DOE tracked water use and used water tracers to help track its movement. The purpose of these actions was to minimize loss of this water to the subsurface environment and to ensure that subsurface water use did not adversely affect either future repository performance or ongoing site investigations (DIRS 102197-CRWMS 1997, all). This careful use of water in the subsurface would continue during additional repository excavation. Given the mechanisms to remove the water (excavated rock removal, ventilation, and pumping) and the careful use of water in the subsurface, along with the relatively minor importance of Yucca Mountain recharge to the local and regional groundwater system, DOE expects perturbations in recharge through Yucca Mountain to be of small impact to the local and regional groundwater system.

No additional land disturbance would occur from monitoring and maintenance activities and, therefore, there would be no notable impacts to infiltration rates in the area. There would be no additional land disturbance during closure. The implementation of soil reclamation and revegetation would accelerate a return to more natural infiltration conditions. If DOE built a monument (or monuments) to provide a long-lasting marker for the site, its location could be impermeable and thus could generate minor amounts of additional runoff to drainage channels.

Potential for Contaminant Migration to Groundwater

Section 4.1.3.2 discusses the types of potential contaminants that could be present at the repository surface facilities during the various phases of its active life. It also discusses the possibility of spills or releases of these materials to the environment.

To pose a threat to groundwater, a contaminant would have to be spilled or released and then carried down either by its own volume or with infiltrating water. The depth to groundwater, the thickness of alluvium in the area, and the arid environment would combine to reduce the potential for a large contaminant migration, as would adherence to regulatory requirements and plans such as a Spill Prevention Control and Countermeasure Plan (see Section 4.1.3.2). Section 4.1.8 further discusses the potential for onsite accidents that could involve a release of contaminants. Chapter 5 discusses the long-term postclosure release of contaminants from the waste packages emplaced in the repository.

Groundwater Resources

The quantity of water necessary to support the Proposed Action would be greatest during the initial construction phase and the operation and monitoring phase. Peak demand would occur while DOE was emplacing nuclear material in completed drifts (tunnels) at the same time it was developing other drifts. Table 4-11 summarizes the estimated water demands during these two phases and during closure. Water demand during construction would depend on the operating mode employed. The lower-temperature operating mode would involve emplacement of less spent fuel per unit of repository footprint area, which correlates with increased excavation and increased water to support that excavation.

Table 4-11. Annual water demand for construction, operation and monitoring, and closure.[a]

Phase	Duration (years)	Water demand (acre-feet per year)[a]	
		Higher-temperature	Lower-temperature
Construction	5	160	190 - 210
Operation and monitoring			
Operations period[b]			
Emplacement and development	22	230	250 - 290
Subsequent emplacement only	2 or 28	180	90 - 190
Monitoring period			
Initial decontamination	3	220	200 - 230
Subsequent monitoring and caretaking	73 - 300	6	3 - 6
Closure	10 - 17	81	70 - 84

a. To convert acre-feet to cubic meters, multiply by 1,233.49. Acre-feet are presented because of common public knowledge of this area.
b. Development of the subsurface area would last 22 years for the Proposed Action and emplacement would continue another 2 years without aging. If aging was included, emplacement would not be completed until 28 years beyond the completion of development.

As listed in Table 4-11, water demand during the initial construction phase would range from about 200,000 to 260,000 cubic meters (160 to 210 acre-feet) per year under the range of operating modes. Water demand during the operations period would also vary by operating mode and could range from about 280,000 to 360,000 cubic meters (230 to 290 acre-feet) per year. Once subsurface development was complete and only emplacement was occurring, the estimated annual water demand would range from 110,000 to 230,000 cubic meters (90 to 190 acre-feet). The low end of this range would occur only if the aging facility was included, but it would last for about 26 years while the spent nuclear fuel on the surface pad completed its 30-year cooldown period and DOE gradually moved it to the subsurface. The first 3 years of the monitoring period would include facility decontamination efforts and would require water at a rate varying from 250,000 to 280,000 cubic meters (200 to 230 acre-feet) per year. After the first 3 years, water demand would drop substantially to estimated levels of only 3,700 to 7,400 cubic meters (3 to 6 acre-feet) for the duration of the monitoring period. The closure phase would require about 86,000 to 100,000 cubic meters (70 to 84 acre-feet) per year.

The water demand would be met by pumping from wells in the Jackass Flats hydrographic area, using existing wells J-12, J-13, and the C-well complex. Nevada Test Site activities in this same area also withdraw water from this hydrographic area. This ongoing demand from Nevada Test Site activities has an effect on the affected environment and would continue to represent part of the demand from the Jackass Flats hydrographic area. Consequently, this additional water demand is discussed here and as part of the cumulative impacts in Chapter 8.

DOE evaluated potential impacts of the water demands on area groundwater resources by three methods:

- Consideration of impacts observed or measured during past water withdrawals
- Comparison of the proposed demand to the perennial yield of the aquifer supplying the water
- Groundwater modeling efforts to assess any changes the proposed demand would have on groundwater elevations and flow patterns

Groundwater Demand During Construction

During the initial construction phase, the estimated water demand from the Jackass Flats hydrographic area would be about 540,000 to about 600,000 cubic meters (440 to 490 acre-feet) a year, including the ongoing demand from Nevada Test Site activities [projected to be 340,000 cubic meters (280 acre-feet) a year (DIRS 103226-DOE 1998, Table 11-2, p. 11-6)]. This quantity is very similar to the roughly 490,000 cubic meters (400 acre-feet) withdrawn from the Jackass Flats area in 1996 (see Chapter 3, Table 3-16). The level of water demand during the construction phase probably would result in declines in water levels in the production wells and nearby. DOE expects the amount of decline to be similar to the groundwater level fluctuations discussed in Chapter 3, Section 3.1.4.2.2 (see Table 3-17), during which elevation decreases as large as 6 to 12 centimeters (2.4 to 4.7 inches) occurred in the production wells over a 6-year period. However, this decline would diminish to undetectable levels as the distance from the repository increased and would result in very small effects to the overall groundwater system.

Effect of Operations on Groundwater Perennial Yield

As the Proposed Action would move from construction into the operation and monitoring phase, groundwater withdrawal rates would increase. The following discussion of impacts centers on comparisons to the perennial yield of the groundwater basin supplying the water.

Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir. As discussed in Chapter 3, Section 3.1.4.2, the estimated perennial yield of the aquifer in the Jackass Flats hydrographic area is between 1.1 million and 4.9 million cubic meters (880 and 4,000 acre-feet) (DIRS 104954-Thiel 1997, p. 8). However, as indicated in footnote f to Table 3-11 in Chapter 3, the low estimate of perennial yield for Jackass Flats is accompanied by the qualification that 370,000 cubic meters (300 acre-feet) is attributed to the eastern one-third of the area, and 720,000 cubic meters (580 acre-feet) is attributed to the western two-thirds where wells J-12 and J-13 are located. This distinction was made to be consistent with the belief of some investigators that the two portions of Jackass Flats have different general flow characteristics. Assuming this is correct, the most conservatively low estimate of perennial yield applicable to the location of wells J-12 and J-13 would be 720,000 cubic meters (580 acre-feet). The highest estimated water demand during the operation and monitoring phase would not exceed this lowest estimate of perennial yield, and it would represent only about 7 percent of the higher estimate of perennial yield.

A past DOE application for a water appropriation from Jackass Flats resulted in a State Engineer's ruling (DIRS 105034-Turnipseed 1992, pp. 9 to 11) that described the perennial yield of Jackass Flats (Hydrographic Area 227A) as 4.9 million cubic meters (4,000 acre-feet). The same ruling identified the estimated annual recharge for the western two-thirds of this hydrographic area as 720,000 cubic meters (580 acre-feet). Based on this information, the estimates of perennial yield for this hydrographic area range from consideration of only the amount of recharge that occurs in the area to inclusion of underflow that enters the area from upgradient groundwater basins. If the groundwater is basically in equilibrium under current conditions (which should be a reasonable assumption based on the stability of the water table elevation), then withdrawing more than 720,000 cubic meters probably would result in additional underflow entering the immediate area to maintain the equilibrium level. Under this scenario, pumping more than 720,000 cubic meters from the western portion of Jackass Flats would be unlikely to cause a depletion of the reservoir, and instead could result in shifting of the general groundwater flow patterns. Because the amount pumped would be much less than the upper estimates of perennial yield (that is, the total amount of available water moving through the area, not just the recharge from precipitation), changes in general flow patterns probably would be small.

With the addition of repository water usage to the baseline demands from Nevada Test Site activities, the highest estimated demand from the Jackass Flats area during the initial construction phase would be about 600,000 cubic meters (490 acre-feet) per year. This demand would be below the lowest estimate of the area's perennial yield [720,000 cubic meters (580 acre-feet) for the western two-thirds of Jackass Flats]. Maximum repository water demands would occur during the operations period (Table 4-11), which when combined with the baseline demands from Nevada Test Site activities would approach but still be below the lowest perennial yield estimate. None of the water demand estimates would approach the high estimates of perennial yield [4.9 million cubic meters (4,000 acre-feet)].

On a regional basis in the Alkali Flat-Furnace Creek groundwater basin, the heaviest water demand is in the Amargosa Desert. Over the period of the repository project's need for water, additional water consumption in upgradient hydrographic areas would to some extent decrease the availability of water in the valley (DIRS 103099-Buqo 1999, pp. 37, 38, and 52). That is, consumption would not necessarily exceed the perennial yield of the Jackass Flats hydrographic area, but it could reduce the long-term amount of underflow that would reach the Amargosa Desert, effectively decreasing the perennial yield of that hydrographic area. However, the maximum projected demands for the repository and the Nevada Test Site during the construction phase [about 600,000 cubic meters (490 acre-feet) a year] and the operation and monitoring phase [about 700,000 cubic meters (570 acre-feet)] would be small in comparison to the 17 million cubic meters (14,000 acre-feet) pumped in the Amargosa Desert annually from 1995 through 1997 (see Table 3-11). The demand of the repository and the Nevada Test Site would be even a smaller fraction of the perennial yield of 30 million to 40 million cubic meters (24,000 to 32,000 acre-feet) in the Amargosa Desert.

Potential Changes to Groundwater Elevation

Two separate modeling efforts have assessed potential changes to groundwater elevations and flow patterns as a result of water demands from the proposed repository action. One study (DIRS 145966-

CRWMS M&O 2000, all) was performed by Thiel Engineering Consultants for DOE; the other study (DIRS 145962-Tucci and Faunt 1999, all) was performed by the U.S. Geological Survey. Both efforts included the modeling of baseline conditions that included historical water withdrawals from the Jackass Flats area followed by modeling of future water withdrawals that include the baseline and an additional annual water demand of 530,000 cubic meters (430 acre-feet) for the proposed repository. The studies focused on the predicted differences between the baseline and future simulations in the groundwater flow regime of Jackass Flats and surrounding hydrographic areas, particularly the Amargosa Desert (see Figure 3-17). The Thiel Engineering Consultants study included the use of transient models (DIRS 145966-CRWMS M&O 2000, p. 2) to project changes in groundwater levels and flow patterns. It utilized several different assumed groundwater withdrawal scenarios over this area, with and without the water demand for the repository project, and simulated the withdrawal scenarios for 100 years. The U.S. Geological Survey effort compared the results of two steady-state simulations (baseline and predictive future) of the regional groundwater flow system. Results of the simulations indicated that there would be groundwater elevation differences (between conditions with and without the Proposed Action) as described in the following summary statements:

- The Thiel Engineering Consultants study predicted a water elevation decrease of up to 3 meters (10 feet) within about 1 kilometer (0.6 mile) of the Yucca Mountain production wells as a result of the Proposed Action's water demand (DIRS 145966-CRWMS M&O 2000, p. 86). The U.S. Geological Survey model resulted in similar projections, predicting a water level decrease of less than 2 meters (6.6 feet) at distances of a few kilometers from the production wells (DIRS 145962-Tucci and Faunt 1999, p. 13).

- The models predicted water elevation decreases at the town of Amargosa Valley ranging from less than 0.4 meter (1.2 feet) (DIRS 145966-CRWMS M&O 2000, all) to 1.1 meters (3.6 feet) (DIRS 145962-Tucci and Faunt 1999, p. 13).

- Both models generated predictions of the reduction in underflow from the Jackass Flats hydrographic area to the Amargosa Desert hydrographic area that would result from the Proposed Action. The Thiel Engineering Consultants (DIRS 145966-CRWMS M&O 2000, p. 89) study estimates a flow reduction of about 160,000 cubic meters (130 acre-feet) per year after 100 years of pumping. The U.S. Geological Survey (DIRS 145962-Tucci and Faunt 1999, p. 13) effort estimates 180,000 cubic meters (150 acre-feet) per year at steady-state conditions.

The Thiel Engineering Consultants modeling effort looked at numerous locations and pumping scenarios throughout the groundwater region. The results indicated that in all areas of the Amargosa Desert, the decreases in groundwater elevation attributed to the Proposed Action would be minor in comparison to those simulated for the areas without the Proposed Action (DIRS 145966-CRWMS M&O 2000, pp. 173 to 184). Both models evaluated a hypothetical Yucca Mountain Project water demand of 530,000 cubic meters (430 acre-feet) per year, which is the quantity planned for the site's application for a water appropriation. As listed in Table 4-11, the highest estimate of the Proposed Action's annual water demand is only about 67 percent of this quantity. Had this smaller number been used in the models, a corresponding decrease in the predicted effects would have resulted. The Proposed Action's higher periods of water demand [that is, periods with annual water demand near or above 250,000 cubic meters (200 acre-feet)] would total only about 30 years compared to the 100 years of demand at the higher rate used in the Thiel Engineering Consultants study.

Monitoring Period

Water demand for monitoring and maintenance activities would be much less than that for emplacement and development activities, particularly after the completion of decontamination activities, which would take place during the first 3 years of the monitoring period. Routine monitoring and maintenance activities would involve minimal water needs.

Closure Phase

The annual demand during closure would vary by a small amount based on the operating mode used, but would be less than 30 percent of the maximum demand during the operation and monitoring phase and, similarly, would have minor impacts on groundwater resources.

Summary of Impacts to Hydrology

The conclusions of the evaluations discussed in this section are as follows:

- Repository operation would result in minor changes to runoff and infiltration rates.
- The potential for flooding at the repository site is extremely small.
- Water demand under highest consumption conditions would be below the Nevada State Engineer's ruling of perennial yield (the amount that can be withdrawn annually without depleting reserves) for the Jackass Flats groundwater basin. The highest demand conditions in combination with ongoing Nevada Test Site demand from the same basin would also be below the lowest estimates of perennial yield.
- The combined water demand of the repository and the Nevada Test Site would, at most, have minor impacts on the availability of groundwater in the Amargosa Valley in comparison to the quantities of water already being withdrawn there.

DOE filed an application for permanent water rights with the State of Nevada for the projected water needs to meet DOE's responsibilities under the NWPA. Uses for the water would include, but not be limited to, road construction, facility construction, drilling, dust suppression, drift and pad construction, testing, culinary, domestic, and other related site uses. On February 2, 2000, the Nevada State Engineer denied the application on the basis that the proposed use threatens to prove detrimental to the public interest because the proposed use (that is, supporting the repository action) is prohibited by existing State law. On March 2, 2000, DOE filed an appeal of the State Engineer's decision (DIRS 151945-CRWMS M&O 2000, pp. 9.5-5 and 9.5-6). On October 15, 2001, the U.S. Court of Appeals (9th Circuit) remanded the case back to the Nevada District Court for a hearing on the merits. At the time this EIS was prepared, the appeal was still in process and a final outcome for the water appropriation application had not been determined.

4.1.4 IMPACTS TO BIOLOGICAL RESOURCES AND SOILS

The evaluation of impacts to biological resources considered the potential for affecting sensitive species (plants and animals) and their habitats, including areas of critical environmental concern; sensitive, threatened, or endangered species, including their habitats; jurisdictional waters of the United States, including wetlands; and riparian areas. The evaluation also considered the potential for impacts to migratory patterns and populations of game animals. DOE expects the overall impacts to biological resources to be very small. Biological resources in the Yucca Mountain region include species typical of the Mojave and Great Basin Deserts and generally are common throughout those areas. Neither the removal of vegetation from the small area required for the repository nor the very small impacts to some species would affect regional biodiversity and ecosystem function.

Section 4.1.4.1 describes potential impacts to biological resources and soils from preconstruction testing and performance confirmation activities. Section 4.1.4.2 describes potential impacts to biological

Main Index Vol 1 Index

resources from construction, operation and monitoring, and closure. Section 4.1.4.3 describes the evaluation of the severity of potential impacts to biological resources. Section 4.1.4.4 describes potential impacts to soils from construction, operation and monitoring, and closure.

4.1.4.1 Impacts to Biological Resources and Soils from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities could require additional land disturbance, and current vehicle traffic at the site of the proposed repository would continue. Impacts to biological resources from additional land disturbance could consist of the loss of a small amount of available habitat for terrestrial plant and animal species, including desert tortoises, in widely distributed land cover types and the deaths of a small number of individuals of some terrestrial species. The actual amount of additional land disturbance, if any, is uncertain. DOE expects it to be much less than the quantity of disturbance during site characterization.

The limited habitat loss from additional land disturbance would have little impact on plant and animal populations because habitats similar to those at Yucca Mountain are widespread locally and regionally. Similarly, the deaths of small numbers of individuals of some species, primarily burrowing species of small mammals and reptiles, would have little impact on the regional populations of those species. The animal species at the Yucca Mountain site are generally widespread throughout the Mojave or Great Basin Deserts.

Impacts to desert tortoises from preconstruction testing and performance confirmation would be less than impacts that occurred during site characterization, during which five tortoises have been killed on roads at Yucca Mountain (DIRS 104593-CRWMS M&O 1999, p. 3-12). Habitat loss during the peak of site characterization did not have a detectable effect on the survival, reproduction, behavior, or disease status of desert tortoises living adjacent to construction activities at Yucca Mountain (DIRS 104294-CRWMS M&O 1999, all). Because the desert tortoise is a *threatened species*, it would continue to receive special consideration during land-disturbing activities. DOE would continue to work with the U.S. Fish and Wildlife Service and would implement the terms and conditions required by the Service to minimize impacts to desert tortoises at the site (see Appendix O). Thus, preconstruction testing and performance confirmation would have very little or no impact on the desert tortoise population at Yucca Mountain or along roads traveled to the site.

The potential for soil impacts such as erosion would increase slightly, but erosion control measures, such as dust suppression, would ensure that impacts were very small.

4.1.4.2 Impacts to Biological Resources from Construction, Operation and Monitoring, and Closure

This section describes potential short-term impacts to biological resources at the Yucca Mountain site from construction, operation and monitoring, and closure activities. The primary sources of such impacts would be related to habitat loss or modification during facility construction and operations and to human activities, such as increased traffic, associated with the repository. In addition, this section identifies and evaluates potential impacts to vegetation; wildlife; special status species; and jurisdictional waters of the United States, including wetlands, over the projected life of the project and during each phase of the project.

Routine releases of radioactive materials from the repository would consist mainly of naturally occurring radon-222 and its decay products (see Section 4.1.2 and Appendix G, Section G.2). These releases would result in very small doses to plants and animals around the repository. Estimated doses to humans working and living near the site would be very small (as described in Section 4.1.7). The International

Atomic Energy Agency has concluded that chronic dose rates less than 100 *millirad* per day to plants and animals are unlikely to cause measurable detrimental effects in populations of even the more radiosensitive species in terrestrial ecosystems (DIRS 103277-IAEA 1992, p. 53). Expected dose rates to plants and animals would be much less than 100 millirad per day. Therefore, no detectable impacts to biological resources would occur as a result of normal releases of radioactive materials from the repository, and the following sections do not consider these releases.

Impacts to Vegetation

The construction of surface facilities and the disposition of rock excavated during subsurface construction would remove or alter vegetation. Much of the construction would occur in areas in which site characterization activities had already disturbed the vegetation; however, construction would also occur in undisturbed areas near the previously disturbed areas. Subsurface construction would continue after emplacement operations began, and the disposal of excavated rock would eliminate vegetation in the area covered by the excavated rock pile. The total amount of land cleared of vegetation would vary among the repository operating modes (Table 4-12).

Table 4-12. Land cover types in the land withdrawal area and the amount of each that repository construction and disposal of excavated rock would disturb (square kilometers).[a,b]

			Area that would be disturbed	
Land cover type[c]	Area in Nevada	Land withdrawal area	Higher-temperature	Lower- temperature
Blackbrush	9,900	140	0.0	0.0 - 0.2
Creosote-bursage	15,000	300	0.6	0.6 - 0.7
Mojave mixed scrub	5,700	120	2.2	2.4 - 3.6
Sagebrush	67,000	16	0.0	0.0
Salt desert scrub	58,000	20	0.0	0.0
Previously disturbed	NA[d]	4	1.5	1.5
Totals[e]	***NA***	***600***	***4.3***	***4.5 - 6.0***

a. Source: Derived from facility diagrams from DIRS 104523-CRWMS M&O (1999, all) and land cover types maps and vegetation associations (DIRS 102303-CRWMS M&O 1998, all) using a Geographic Information System.
b. To convert square kilometers to acres, multiply by 247.1.
c. A small area (0.016 square kilometer) of the piñon-juniper-2 land cover type occurs in the analyzed land withdrawal area, but would not be affected.
d. NA = not applicable.
e. Totals might differ from sums due to rounding.

Five of the 65 different land cover types (defined primarily by dominant vegetation) identified in the State of Nevada occur in the approximately 600-square-kilometer (230-square-mile) analyzed land withdrawal area around the repository site (Table 4-12). Surface disturbances resulting from repository activities would occur in three of these land cover types and in previously disturbed areas (Table 4-12). Repository construction would disturb less than 1 percent of the withdrawal area, which would be an extremely small percentage of the undisturbed vegetation available in the withdrawal area.

Repository construction, including the disposal of material in the excavated rock pile after the start of emplacement, would occur primarily in previously disturbed areas or areas dominated by creosote-bursage and Mojave mixed scrub.

Repository construction activities in undisturbed vegetation could result in additional areas where colonization by exotic plant species could occur. Exotic species that are currently present on the site (see Section 3.1.5.1.1) would be the most likely *invasive species*. *Native species* could be suppressed in areas colonized by exotic species and there could be an increase in fire fuel load associated with dried annual plant species. Because the undisturbed vegetated area that would be disturbed by construction is small compared to the total undisturbed vegetated area, impacts to native species and the threat of increased fires would also be small.

Studies from 1989 to 1997 indicated that site characterization activities had very small effects on vegetation adjacent to the activities (DIRS 104593-CRWMS M&O 1999, pp. 2-2 through 2-4). Therefore, impacts to vegetation from repository construction probably would occur only as a result of direct disturbance, such as during site clearing. Little or no disturbance of additional vegetation would occur as a result of monitoring and maintenance activities before closure. DOE would reclaim lands no longer needed for repository operation.

Activities associated with the closure of the repository could involve the removal of structures and reclamation of areas cleared of vegetation for the construction of surface facilities. Closure would involve minimal, if any, new disturbance of vegetation. Reclamation activities would enhance the recovery of native vegetation in disturbed areas and reduce colonization by exotic species.

Impacts to Wildlife

The construction of surface facilities and excavated rock disposal would lead to habitat losses for some terrestrial species (Chapter 3, Section 3.1.5); however, habitats similar to those at Yucca Mountain (identified by land cover type) are widespread locally and regionally. In addition to habitat loss, the conversion of undisturbed land to industrial uses associated with the repository would result in the localized deaths of individuals of some species, particularly burrowing species of small mammals and reptiles. Birds, carnivores, and ungulates (mule deer or burros) at the repository site would be less likely to be killed during construction because they would be able to move away from areas of human activity.

The construction of new roads, surface facilities, and other infrastructure would lead to fragmentation of previously undisturbed habitat. Nevertheless, DOE anticipates impacts to wildlife populations to be very small because large areas of undisturbed and unfragmented habitat would be available away from disturbed areas.

Animal species present at the repository location are generally widespread throughout the Mojave or Great Basin Deserts and the deaths of some individuals due to repository construction and habitat loss would have little impact on the regional populations of those species. Site characterization activities had no detectable effect on populations of small mammals, side-blotched lizards, and desert tortoises in areas adjacent to the activities (DIRS 104593-CRWMS M&O 1999, pp. 2-4, 2-5, 2-7, and 3-10 to 3-12).

In addition to direct losses due to the construction of surface facilities and excavated rock disposal, individuals of some species would be killed by vehicles traveling to and from the Yucca Mountain site during the construction, operation and monitoring, and closure phases (DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). These losses would have a very small effect on populations because species at the site are widespread. No species would be threatened with extinction, either locally or globally.

Noise and ground vibrations generated during repository construction and operations could disturb wildlife and cause some animals to move away from or avoid the source of the noise. Impacts to wildlife from noise and vibration, if any, would decline as the distance from the source of the noise (the repository) increased. Noise levels would drop below the limit of human hearing at a distance of about 6 kilometers (3.7 miles) from the repository (see Section 4.1.9) and no noise-related impacts to wildlife would be likely at that distance. Animals may acclimate to the noise, limiting the area affected by repository-related noise to the immediate vicinity of the source of the noise (heavy equipment, diesel generators, ventilation fans, etc.).

Several animals classified as game species by the State of Nevada (Gambel's quail, chukar, mourning doves, and mule deer) are present in low numbers in the analyzed Yucca Mountain land withdrawal area.

Adverse impacts to these species would be unlikely, and offsite hunting opportunities probably would not decline.

DOE would dispose of industrial wastewater in lined evaporation ponds in the North Portal Operations Area and South Portal Development Area. Wildlife would be attracted to the water in these ponds to take advantage of this otherwise scarce resource. Individuals of some species could benefit from the water, but some animals could become trapped in the ponds, depending on the depth and the slope of the sides. Monitoring at similar lined evaporation ponds on the Nevada Test Site has shown that a wide variety of animal species use the ponds and that DOE could avoid losses of animals by reducing the slopes of the ponds or by providing an earthen ramp at one corner of the lined pond (DIRS 103075-Bechtel 1997, p. 31). Appropriate engineering would minimize potential losses to wildlife.

DOE does not anticipate adverse effects on wildlife that used the nonhazardous, nontoxic wastewater discharged to the evaporation ponds. Industrial wastewater routed to the evaporation pond at the North Portal would be nonhazardous. DOE anticipates that the primary chemical constituents in the water would be sodium and calcium carbonates, with smaller amounts of chlorides, sulfates, and fluorides. Metal constituents could include potassium, zinc, iron, magnesium, and manganese. Wastewater discharged to the South Portal evaporation pond would be nontoxic wastewater derived from dust suppression activities; it would contain small particles of mined rock along with Portland Cement and fine aggregate particles from concrete mix plants. DOE would maintain the pH of the water within a defined range through the addition of acceptable additives. Water quality would be monitored and appropriate measures to protect wildlife would be implemented.

DOE would construct a landfill for construction debris and sanitary solid waste. The landfill could attract scavengers such as coyotes and ravens. Frequent covering of the sanitary waste disposed of in the landfill could minimize use by scavenger species.

After the completion of emplacement, human activities and vehicle traffic would decline, as would impacts of those actions on wildlife, with further declines in activities and impacts after repository closure. Animal species would reoccupy the areas reclaimed during closure activities.

Impacts to Special Status Species

The desert tortoise is the only resident animal species in the analyzed land withdrawal area listed as threatened under the Endangered Species Act of 1973 (16 U.S.C. 1531, *et seq.*). There are no endangered or candidate animal species and no species that are proposed for listing (DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). Repository construction would result in the loss of a very small portion of the total amount of desert tortoise habitat at the northern edge of the range of this species in an area where the abundance of desert tortoises is low (DIRS 102869-CRWMS M&O 1997, pp. 6 to 12; DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12).

Based on past experience, DOE anticipates that human activities at the site could directly affect individual desert tortoises. During site characterization activities, 28 tortoises and two tortoise nests were relocated because of threats from construction activities (DIRS 103194-CRWMS M&O 1998, pp. 3 to 17; DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). All but one of the 28 individual relocations and both nest relocations were successful. Five tortoises (including the one unsuccessful relocation) have been killed as a result of site characterization activities; all were killed by vehicles on roads (DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). DOE would conduct surveys and would move tortoises that it found; however, based on experience from site characterization, DOE anticipates the deaths of small numbers of individual tortoises from vehicle traffic and construction activities during the repository construction, operation and monitoring, and closure phases.

Although these losses would cause a small decrease in the abundance of desert tortoises in the immediate vicinity of the repository site, they would not affect the long-term survival of the local or regional population of this species. Yucca Mountain is surrounded to the east, south, and west by large tracts of undisturbed tortoise habitat on government property, and desert tortoises are widespread at low densities throughout this region. Habitat loss caused by transportation and other activities during site characterization did not have a detectable effect on the survival, reproduction, behavior, or disease status of desert tortoises living adjacent to construction activities at Yucca Mountain (DIRS 104294-CRWMS M&O 1999, all). In addition, the abundance of ravens at Yucca Mountain did not increase as a result of site characterization activities (DIRS 102236-CRWMS M&O 1998, pp. 9 through 12), and ravens were not an important cause of mortality of small tortoises during that period (DIRS 103195-CRWMS M&O 1998, p. 8).

The U.S. Fish and Wildlife Service has concluded that tortoise populations are depleted for more than a kilometer on either side of heavily used roads (DIRS 102475-Brussard et al. 1994, p. D12). The increase in traffic to Yucca Mountain (see Appendix J, Section J.3.6) would contribute to the continued depression of populations immediately adjacent to U.S. Highway 95, but would not increase the threat to the long-term survival of desert tortoise populations in southern Nevada.

As required by Section 7 of the Endangered Species Act, DOE has completed consultations with the Fish and Wildlife Service concerning the effects of repository construction, operation and monitoring, and closure on the desert tortoise. The U.S. Fish and Wildlife Service has issued a Biological Opinion establishing reasonable and prudent measures and terms and conditions to ensure that implementation of the Proposed Action would not jeopardize the desert tortoise (see Appendix O). The Biological Opinion also contains an incidental take permit. DOE would implement all the measures and terms and conditions of the Biological Opinion to protect the desert tortoise around Yucca Mountain.

The bald eagle and peregrine falcon have been observed once each on the Nevada Test Site and might migrate through the Yucca Mountain region. If present at all, these species would be transient and would not be affected. Bald eagles are classified as threatened under the Endangered Species Act. The State of Nevada classifies the bald eagle and the peregrine falcon as endangered.

Several animal species considered sensitive by the Bureau of Land Management [two bats—the long-legged myotis and fringed myotis—and the western chuckwalla, burrowing owl, and Giuliani's dune scarab beetle; (see Chapter 3, Section 3.1.5)] occur in the analyzed land withdrawal area. Impacts to the bat species would be very small because of their low abundance on the site and broad distribution. Impacts to the Western chuckwalla and burrowing owl would be very small because they are widespread regionally and are not abundant in the land withdrawal area. Giuliani's dune scarab beetle has been reported only in the southern portion of the land withdrawal area, away from any proposed disturbances.

Monitoring and closure activities at the repository would have little impact on desert tortoises, or Bureau of Land Management sensitive species. Over time, vegetation would recover on disturbed sites and indigenous species would return. As the habitat recovered over the long term, desert tortoises and other special status species at the repository site would recolonize areas abandoned by humans.

Impacts to Wetlands

There are no known naturally occurring jurisdictional wetlands (that is, wetlands subject to permitting requirements under Section 404 of the Clean Water Act) on the repository site, so no impacts to such wetlands would occur as a result of repository construction, operation and monitoring, or closure. In addition, repository construction, operation and monitoring, and closure would not affect the four manmade well ponds in the Yucca Mountain region. Repository-related structures could affect as much as 2.8 kilometers (1.7 miles) of ephemeral washes, depending on the size and location of such facilities as the excavated rock storage area. Although no formal delineation has been undertaken, some of these washes might be waters of the United States. After selecting the location of facilities, DOE would conduct a formal delineation, as appropriate, to confirm there are no wetlands at Yucca Mountain; formally delineate waters of the United States near the surface facilities; and, if necessary, develop a plan to avoid when possible, and otherwise minimize, impacts to those waters. If repository activities would affect waters of the United States, DOE would consult with the U.S. Army Corps of Engineers and obtain permit coverage for those impacts. If the activities were not covered under a nationwide permit, DOE would apply to the Corps of Engineers for a regional or individual permit. By implementing the mitigation plan and complying with other permit requirements, DOE would ensure that impacts to waters of the United States would be minimized.

4.1.4.3 Evaluation of Severity of Impacts to Biological Resources

DOE evaluated the magnitude of impacts to biological resources and classified the severity of potential impacts as none, very low, or low, as listed and described in Table 4-13.

Table 4-13. Impacts to biological resources.

Phase or period	Flora	Fauna	Special status species	Wetlands	Overall
Initial construction	Very low/low; removal of vegetation from as much as 4.5 square kilometers[a] in widespread communities	Very low; loss of small amount of habitat and some individuals of some species	Low; loss of small amount of desert tortoise habitat and small number of individual tortoises	None	Very low/low; loss of small amount of widespread but undisturbed habitat and small number of individuals
Construction, operation, and monitoring					
Emplacement and development	Very low/low; disturbance of vegetation in areas adjacent to disturbed areas	Very low; deaths of small number of individuals due to vehicle traffic and human activities	Low; potential deaths of very few individuals due to vehicle traffic	None	Very low new impacts to biological resources
Monitoring and maintenance	Very low; no new disturbance of natural vegetation	Very low; same as for operation, but smaller due to smaller workforce	Very low; same as for operation, but smaller due to smaller workforce	None	Very low; small numbers of individuals of some species killed by vehicles
Closure	Very low; decline in impacts due to reduction in human activity	Very low; decline in number of individuals killed by traffic annually	Very low; decline in number of individuals killed by traffic annually	None	Very low; decline in impacts due to reduction of human activity
Overall rating of impacts	Very low/low	Very low	Very low/low	None	Very low

a. 4.5 square kilometers = 1,100 acres (6.0 square kilometers total area, including areas previously disturbed by site characterization).

4.1.4.4 Impacts to Soils from Construction, Operation and Monitoring, and Closure

This section identifies potential consequences to soils as a result of the Proposed Action. Soil-related issues associated with the Proposed Action include the following:

- Potential consequences of soil loss in disturbed areas, either from erosion or displacement
- *Soil recovery* from disturbances
- Potential for spreading contamination by relocating contaminated soils (if present)

Overall, impacts to soils would be minimal. DOE would use erosion control techniques to minimize erosion. Because soil in disturbed areas would be slow to recover, during the closure phase DOE would revegetate the area that it had not reclaimed after the temporary disturbances following construction.

Soil Loss

Land disturbed at the repository site could, at least for a short period, experience increased erosion. Erosion is a two-step process of (1) breaking away soil particles or small aggregates and (2) transporting those particles or aggregates. Land disturbance that removed vegetation or otherwise broke up the natural surface would expose more small materials to the erosion process, making the soil more susceptible to wind and water erosion. Activities during the construction and operation and monitoring phases would disturb varying amounts of land depending on the operating mode used for the repository. Most of the variation would be due to the emplaced waste being spaced further apart under the lower-temperature operating mode, resulting in more excavated rock being stored on the surface and more ventilation shafts extending from the repository to the surface. A decision to incorporate an aging facility would increase the amount of land disturbed. The highest estimate of newly disturbed land as a result of the Proposed Action is about 4.5 square kilometers (1,100 acres).

Site characterization activities at Yucca Mountain included a reclamation program with a goal to return the disturbed land to a condition similar to its predisturbance state (DIRS 154386-YMP 2001, p. 1). One of the benefits of achieving such a goal would be the minimization of soil erosion. The program included the implementation and evaluation of topsoil stockpiling and stabilization efforts that would enable the use of topsoil removed during excavation in future reclamation activities. The results were encouraging enough to recommend that these practices continue. This action would reduce the construction loss of the most critical type of soil. Fugitive dust control measures including water spraying and chemical treatment would be used as appropriate to minimize wind erosion of the stockpiled topsoil and excavated rock. Based on site characterization experience and the continued topsoil protection and erosion control programs, DOE does not anticipate much soil erosion during any phase of the project.

If the Proposed Action was implemented, program planning developed for site characterization (DIRS 104837-DOE 1989, pp. 2 and 20) specifies that reclamation would occur in all areas disturbed during characterization activities that are not needed for the operation of the repository. As a result, prior land disturbances should represent minimal soil erosion concern during the Proposed Action.

Recovery

Studies performed during the Yucca Mountain site characterization effort (DIRS 104837-DOE 1989, all; DIRS 102188-YMP 1995, all) looked at the ability of the soil ecology to recover after disturbances. These studies and experience at the Nevada Test Site indicate that natural succession on disturbed arid lands would be a very slow process (DIRS 104837-DOE 1989, p. 17; DIRS 102188-YMP 1995, p. 1-5). Left alone, and depending on the type or degree of disturbance and the site-specific environmental conditions, the recovery of

> **SOIL RECOVERY**
>
> The return of disturbed land to a relatively stable condition with a form and productivity similar to that which existed before any disturbance.

predisturbance conditions in this area could take decades or even centuries. With this in mind, soil recovery would be unlikely without reclamation. In general, soil disturbances would remain as areas without vegetation and, with the exception of built-up areas, would have an increased potential for soil erosion throughout the construction and operation and monitoring phases.

Contamination

Based on preconstruction testing and characterization activities that took place in the past (Chapter 3, Section 3.1.5.2), radiological and nonradiological characteristics of the site soils are consistent with the area background. Therefore, there would be no need for restrictions or concerns about contamination migration during construction or as a result of soil erosion. There would be a potential for spills or releases of contaminants to occur under the Proposed Action (as discussed in Section 4.1.3), but DOE would continue to implement a Spill Prevention, Control, and Countermeasures Plan [DIRS 104903-K/PB (1997, all) is an example] to prevent, control, and remediate soil contamination.

4.1.5 IMPACTS TO CULTURAL RESOURCES

This section describes impacts to cultural resources from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. The evaluation of such impacts considered the potential for disrupting or modifying the character of archaeological or historic sites and other cultural resources. The evaluation placed particular emphasis on identifying the potential for impacts to historic sites and other cultural resources important to sustaining and preserving Native American cultures. The region of influence for the analysis included land areas that repository activities would disturb and areas in the analyzed land withdrawal area where impacts could occur.

DOE assessed potential impacts to cultural resources from these activities by (1) identifying project activities that could directly or indirectly affect archaeological, historic, and traditional Native American resources possibly eligible for listing on the *National Register of Historic Places*; (2) identifying the known or likely eligible resources in areas of potential impact; and (3) determining if a project activity would have no effect, no adverse effect, or an adverse effect on potentially eligible resources (36 CFR 800.9). Direct impacts would be those from ground disturbances or activities that would destroy or modify the integrity of a given resource considered eligible for listing on the National Register. Indirect impacts would result from activities that could increase the potential for adverse impacts, either intentional or unintentional (for example, increased human activity near potentially eligible resources could result in illicit collection or inadvertent destruction).

4.1.5.1 Impacts to Cultural Resources from Preconstruction Testing and Performance Confirmation

Land disturbances associated with preconstruction testing and performance confirmation activities could have direct impacts to cultural resources in the Yucca Mountain region of influence (see Chapter 3, Table 3-1). Before activities began, therefore, DOE would identify and evaluate archaeological or cultural resources sites in affected areas for their importance and eligibility for inclusion in the *National Register of Historic Places*. DOE would avoid such sites if practical or, if it was not practical, would conduct a data recovery program of the sites in accordance with applicable regulatory requirements and input from the official tribal contact representatives and document the findings. The artifacts from and knowledge about the site would be preserved. Improved access to the area could lead to indirect impacts, which could include unauthorized excavation or collection of artifacts. Workers would have required training on the protection of these resources from excavation or collection.

Main Index Vol 1 Index

4.1.5.2 Impacts to Cultural Resources from Construction, Operation and Monitoring, and Closure

Impacts to archaeological and historic sites could occur during the initial construction phase and the operation and monitoring phase, when ground-disturbing activities would take place. Indirect impacts to archaeological and historic sites could occur during all phases of the Proposed Action.

Archaeological and Historic Resources

Potential impacts to *National Register*-eligible cultural resources from surface facility construction could occur in areas where ground-disturbing activities would take place. Repository development would disturb a maximum of about 4.5 square kilometers (1,100 acres) of previously undisturbed land at the site.

Archaeological investigations conducted in the immediate vicinity of the proposed surface facilities in support of previous and ongoing characterization studies and infrastructure construction have identified about 830 archaeological and historic sites. These investigations have identified resource localities and provided mitigative relief for resources potentially subject to direct impacts (DIRS 104997-CRWMS M&O 1999, Table 2). In addition, ground-disturbing activities associated with potential nearby project actions (for example, upgrades to utility and road rights-of-way, rail access facilities, excavated rock and other onsite storage areas) would occur in areas that had undergone field inventories and evaluations of cultural resources.

Several known archaeological sites in the vicinity of Midway Valley could be affected by ground-disturbing activities associated with the construction of the surface aging facility. An archaeological site occupies much of Midway Valley, including the general location of the proposed surface aging facility. This site was partially mitigated during site characterization activities in 1991 (DIRS 153162-Buck, Amick, and Hartwell 1994, all). In addition, intensive mitigation efforts were conducted at a nearby archaeological site in 1993, yielding nearly 25,000 artifacts (DIRS 153167-Buck et al. 1998, all). Other known archaeological sites occur in the vicinity of the possible location of the solar power generating facility. These sites have not been evaluated beyond field recording, some having been identified more than 20 years ago. One or more of these sites could be affected by construction at the primary location for the solar power generating facility, as well as such features as access roads and transmission cables.

Increases in both surface activities and numbers of workers at the repository site could increase the potential for indirect impacts at archaeological sites near repository surface facilities. Preliminary results from the monitoring of archaeological sites in the vicinity of Yucca Mountain activities since 1991 indicate that human activities and increased access could result in harmful effects, both intentional and inadvertent, to these fragile resources (DIRS 104997-CRWMS M&O 1999, Chapter 1). Indirect impacts are difficult to quantify and control, but they can include loss of surface artifacts due to illicit collection and inadvertent destruction (DIRS 104997-CRWMS M&O 1999, Chapter 1).

Even though there could be some indirect adverse impacts, the overall effect of the repository on the long-term preservation of the archaeological and historic sites in the analyzed land withdrawal area would be beneficial. Cultural resources in the area would be protected from most human intrusion.

Excavation activities at the repository site could unearth additional materials and features in areas that past archaeological surveys have examined only at the surface. Past surveys in the Yucca Mountain area indicated buried cultural materials at some sites with surface artifacts (DIRS 104997-CRWMS M&O 1999, Chapter 1). Thus, excavation activities could unearth previously undetected subsurface features or artifacts. If this happened, work would stop until a cultural resource specialist evaluated the importance of the discovery.

Main Index Vol 1 Index

Native American Viewpoints

DOE would continue the existing Native American Interaction Program (see Chapter 3, Section 3.1.6.2) throughout the Proposed Action. This program promotes a government-to-government relationship with associated tribes and organizations. Continuation of this program during the Proposed Action would enhance the protection of archaeological sites and cultural items important to Native Americans.

The Native American view of resource management and preservation is holistic in its definition of "cultural resource," incorporating all elements of the natural and physical environment in an interrelated context. Moreover, this view includes little or no differentiation between types of impacts (direct versus indirect), but considers all impacts to be adverse and immune to mitigation. Section 4.1.13.4 contains an environmental justice discussion of a Native American viewpoint on the Proposed Action.

Previous studies (DIRS 103465-Stoffle et al. 1990, all; DIRS 102043-AIWS 1998, all) have delineated several Native American sites, areas, and resources in or immediately adjacent to the analyzed land withdrawal area. Construction activities for repository surface facilities would have no direct impacts on these locations. However, because of the general level of importance attributed to these places by Native Americans, and because they are parts of an equally important integrated cultural landscape, Native Americans consider the intrusive nature of the repository to be an adverse impact to all elements of the natural and physical environment (DIRS 102043-AIWS 1998, Chapter 2). In their view, the establishment of the protected area boundary and construction of the repository would continue to restrict the free access of Native American people to these areas. On the other hand, the Consolidated Group of Tribes and Organizations has recognized that past restrictions on public access due to site characterization have resulted in generally beneficial and protective effects for cultural resources, sacred sites, and potential traditional cultural properties (DIRS 102043-AIWS 1998, Chapter 2).

The potential for indirect impacts from construction activities and more workers in the area would increase, particularly to the physical evidence of past use of the cultural landscape (artifacts, cultural features, archaeological sites, etc.) important to Native American people. DOE would continue to provide training to workers to minimize the potential for indirect impacts.

Eventual closure of the repository would have the beneficial effect of returning much of the disturbed landscape to a natural setting. Some additional impacts could occur to resources or areas important to Native Americans if changes in land status or management that occurred after closure led to increased access by the public. The presence of a permanently entombed repository would represent an intrusion into what Native Americans consider an important cultural and spiritual place. Long-term monitoring features or activities would continue to affect these cultural viewpoints.

4.1.6 SOCIOECONOMIC IMPACTS

This section describes potential socioeconomic impacts from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. Evaluations of the socioeconomic environment in communities near the proposed repository site considered changes to employment, economic measures, population, housing, and some public services. The evaluation used the Regional Economic Models, Inc. (REMI) model to estimate baseline socioeconomic conditions and to estimate economic and population changes caused by the Proposed Action. The potential for changes in the socioeconomic environment would be greatest in the Yucca Mountain region of influence where most of the repository workers would live. As discussed in Chapter 3, Section 3.1.7, this region of influence consists of Clark, Lincoln, and Nye Counties in southern Nevada.

DOE examined the maximum potential employment levels that would be required to implement the range of operating modes. The analysis did not project baseline population or employment in the region of influence beyond 2035 because of the speculative nature of such a forecast.

The discussion in this section of changes to population, employment, Gross Regional Product, real disposable income, and expenditures by the State of Nevada and local governments resulting from the Proposed Action are the deviations from a projected baseline for each parameter. This baseline utilizes data DOE received from the State and local governments. Chapter 3, Section 3.1.7 discusses this baseline.

DOE has considered suggestions made in public comments that the EIS include analysis of possible impacts of perceptions associated with the proposed repository. DOE has determined that it could not quantify any potential impacts resulting from such perceptions and that further research would be unlikely to make quantification possible. From a qualitative standpoint, adverse impacts from perceptions of the repository would be unlikely, absent a large accident or a continuing series of smaller accidents. Section 2.5.4 discusses the reasons for DOE's determination.

4.1.6.1 Socioeconomic Impacts from Preconstruction Testing and Performance Confirmation

The level of employment for preconstruction testing and performance confirmation activities would be similar to or less than the current level of employment for site characterization, as described in Chapter 3, Section 3.1.7. Because population and employment changes between ongoing site characterization activities and future performance confirmation activities would be minimal, there would be no meaningful impacts to housing or public services, including impacts to schools.

4.1.6.2 Socioeconomic Impacts from Construction, Operation and Monitoring, and Closure

4.1.6.2.1 *Impacts to Employment*

TERMS RELATED TO EMPLOYMENT

Direct Employment: Jobs expressly associated with project activity.

Indirect Employment: Jobs created as a result of expenditures by directly employed project workers (for example, restaurant workers or child care providers) or jobs created by the project-related purchase of goods and services (for example, sales manager of a concrete supply store).

Composite Employment: Sum of direct and indirect jobs.

In 2006, the peak year of employment during the initial construction phase, about 1,900 additional workers would also be employed on the Yucca Mountain Repository Project. Figure 4-2 shows composite (direct and indirect) employment changes caused by construction activities, by place of residence during this phase. Incremental employment increases during the construction phase attributable to the repository would peak in 2006 with the addition of about 3,400 workers to the region of influence. This would increase overall employment in the region of influence from the projected baseline (employment without the repository project) of approximately 942,000 jobs to slightly less than 945,000 positions, a change of approximately 0.36 percent. Table 4-14 summarizes repository peak year employment during the initial construction period by place of residence in selected communities. Table 4-15 lists the expected residential distribution of directly employed construction workers over the primary construction phase. These tables do not list Lincoln County because, historically, very few Yucca Mountain Project workers have resided in the County. DOE expects that few, if any, repository employees would live in Lincoln County given the long commute.

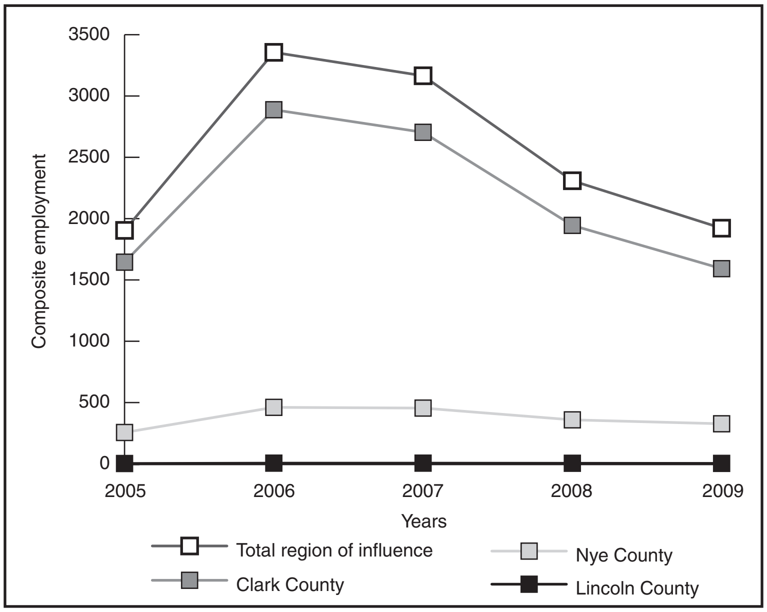


Figure 4-2. Increases in regional composite employment by place of residence during construction phase.

Table 4-14. Expected peak year (2006) increase in construction employment by place of residence in selected communities in Nye and Clark Counties.[a,b,c]

Location	Direct jobs[d]	Indirect jobs[d]	Total jobs[d]
Clark County			
Indian Springs	60	40	100
Rest of Clark County	1,440	1,360	2,800
Clark subtotals	*1,500*	*1,400*	*2,900*
Nye County			
Amargosa Valley	20	10	30
Beatty	3	2	5
Pahrump area	340	90	430
Nye subtotals	*360*	*100*	*460*
Totals[e]	***1,860***	***1,500***	***3,360***

a. Employment and population impacts distributed using residential patterns of Nevada Test Site and Yucca Mountain employees from DOE (DIRS 155987-DOE 2001, all).
b. DOE anticipates approximately 80 percent of repository workers would live in Clark County and approximately 20 percent in Nye County; includes approximately 5 indirect jobs in Lincoln County.
c. Employment in 2006 does not include approximately 220 current workers.
d. Numbers have been rounded to the nearest 10.
e. Totals might not equal sums of values due to rounding.

Table 4-15. Repository direct employment during construction phase by expected county of residence: 2005 to 2009.[a,b,c,d]

County	2005	2006	2007	2008	2009
Clark	1,000	1,660	1,660	1,360	1,300
Nye	240	410	400	330	320
Totals[e]	**1,240**	**2,070**	**2,060**	**1,700**	**1,610**

a. Sources: DIRS 104508-CRWMS M&O (1999, Section 6); DIRS 104523-CRWMS M&O (1999, Section 6).
b. DOE anticipates approximately 80 percent of repository workers would live in Clark County and approximately 20 percent in Nye County.
c. Includes approximately 220 current workers.
d. Numbers are rounded to the nearest 10.
e. Totals might not equal sums of values due to rounding.

Training of operational personnel would begin in 2009. In 2010, direct operational employment would start to increase. Direct operational peak employment would occur in 2012 (with about 2,150 workers). Employment after 2012 would be essentially stable with an average annual workforce of about 1,900 through the year 2033 when operations would be completed.

At the start of the monitoring period, a workforce of up to 1,160 workers would be involved in decontamination of surface facilities for a period of approximately 3 years. The impact to employment from the decontamination activities would be less than 1 percent of the estimated baseline. Figure 4-3 reflects this short-term increase. After decontamination was completed, direct employment would decrease substantially for the remainder of the monitoring period.

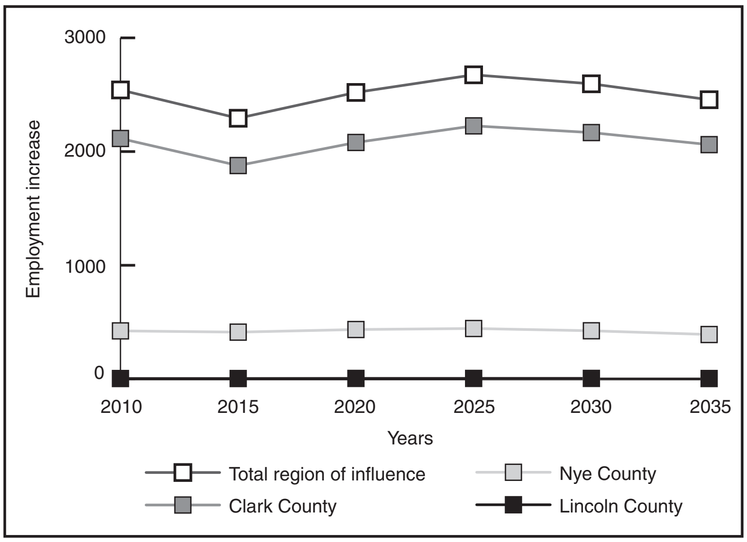


Figure 4-3. Changes in regional employment from operations period and decontamination activities.

Table 4-16 lists the expected residential distribution of repository workers in the peak year of employment (2012) during the operations period. The table also lists the estimated number of indirect jobs created in these communities during 2012. The direct and indirect employment in the region of influence would peak with the addition of approximately 2,700 workers. This would result in an incremental increase of employment from the estimated baseline of about 1,029,000 jobs to about 1,031,000 jobs, a change of less than 0.26 percent from the estimated employment baseline.

Table 4-17 summarizes direct repository employment through the first 24 years of the operation and monitoring phase by county of residence. This table does not list Lincoln County because, historically, so few workers have resided in the County. Figure 4-3 shows the direct and indirect regional employment differences between the bounding employment case for the lower-temperature operating mode with aging and the estimated baseline.

Monitoring and maintenance activities would start with the first emplacement of waste package and would continue through repository closure. DOE estimates that a workforce of approximately 120 workers would be needed to monitor and maintain the repository. Given the expected economic growth in the region of influence, the region could readily absorb declines in repository employment.

To bound this study, the socioeconomic analysis assumes that closure would begin 100 years after the start (and 76 years after the completion) of emplacement activities. The lower-temperature operating mode would require a longer monitoring period, ranging from 125 to 300 years. Therefore, this analysis evaluated potential impacts of a closure of the repository in the lower-temperature mode after as many as

Main Index Vol 1 Index

Table 4-16. Expected peak year (2012) increases in operations period employment in selected communities in Clark and Nye Counties.[a]

Location	Direct jobs[b]	Indirect jobs	Total jobs
Clark County			
Indian Springs	70	20	90
Rest of Clark County	1,490	620	2,110
Clark subtotals	*1,560*	*640*	*2,200*
Nye County			
Amargosa Valley	20	10	30
Beatty	3	0	3
Pahrump area	350	70	420
Nye subtotals	*380*	*80*	*460*
Totals[c]	***1,940***	***720[d]***	***2,660***

a. Numbers have been rounded to the nearest 10.
b. Employment in 2012 does not include approximately 220 current workers.
c. Totals might not equal sums of values due to rounding.
d. Includes 4 indirect workers in Lincoln County.

Table 4-17. Repository direct employment during operations period and decontamination activities by county of residence: 2010 to 2035.[a,b,c]

County	2010	2015	2020	2025	2030	2035[d]
Clark total	1,630	1,600	1,650	1,640	1,560	1,420
Nye total	400	390	400	400	380	350
Totals[c]	***2,030***	***1,990***	***2,050***	***2,040***	***1,940***	***1,770***

a. Includes approximately 220 current workers.
b. Numbers have been rounded to the nearest 10.
c. Totals might not equal sums of values due to rounding.
d. Year 2035 shows the short-term (3-year) impact of decontamination activities.

324 years of operation and monitoring. Employment would be far less than the peak during the operation and monitoring phase and, therefore, would be unlikely to generate employment changes and economic measures of more than one-half of 1 percent. There probably would be no perceptible repository-induced changes to baseline employment in the region of influence. Regional impacts to socioeconomic parameters during the closure phase would be small.

4.1.6.2.2 *Impacts to Population*

From 2010 through 2035 the projected regional population will grow from about 1.9 million residents to approximately 2.8 million. The peak year population contribution attributable to the repository would be approximately 6,200 people, or approximately 0.24 percent of the region of influence's estimated population baseline of 2.6 million people in 2030. As a result, the Yucca Mountain Repository Project would have only small effects on the population growth in the region of influence. Figure 4-4 shows the projected population increase resulting from the repository project.

Table 4-18 lists estimated incremental population increases that would occur as a result of repository activities in Clark and Nye Counties based on historic Nevada Test Site residential distribution patterns. As mentioned above, repository workers would be unlikely to reside in Lincoln County. The incremental peak population increase in Clark County would be less than 0.21 percent.

Population growth associated with the repository would be more evident in Nye County. The County's population increase would be approximately 1.4 percent of the projected population of 77,000, for the County in 2030, the peak year for potential repository population impacts.

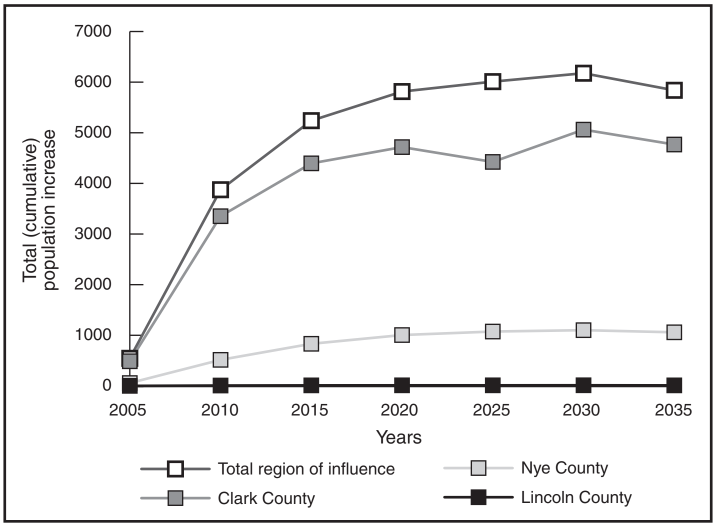


Figure 4-4. Regional population increases from construction and operations: 2000 to 2035.

Table 4-18. Maximum expected population increase from Proposed Action (2030).[a,b]

Location	Population increase
Clark County	
Indian Springs	180
Rest of Clark County	4,880
Clark total	***5,060***
Nye County	
Amargosa Valley	80
Beatty	10
Pahrump	1,000
Nye total	***1,100***

a. Numbers have been rounded to the nearest 10.
b. Totals might not equal sums of values due to rounding.

4.1.6.2.3 *Impacts to Economic Measures*

Table 4-19 lists estimated changes in economic measures that would result from repository activities during the construction phase (values are expressed in 2001 dollars). Increases in real disposable income within the region of influence would peak in 2007 with an increase of about $110 million, while increases in Gross Regional Product would peak in 2006 at about $160 million. Regional expenditures by State and local governments would peak at $11 million in 2009. Economic measures for the region of influence would increase by less than one-third of 1 percent over the projected baseline (estimated economic measures without the repository project).

Table 4-20 lists the changes in economic measures that would result from the repository project duringthe operations period. Increases in Gross Regional Product would peak in 2029 at about $125 million. Increases in real disposable income would peak in 2029 at $149 million. Increases in regional expenditures by State and local governments under the maximum employment case would peak in 2030 at about $22 million. Economic measures for the region of influence would increase by less than 0.5 percent over the projected baseline.

GROSS REGIONAL PRODUCT

The value of all final goods and services produced in the region of influence.

4.1.6.2.4 Impacts to Housing

Given the size of the regional employment, the number of workers in-migrating to work on the repository would be relatively small. Because the inmigration would be small, the increased demand for housing would also be small.

Main Index
Vol 1 Index

Table 4-19. Increases in economic measures within the region of influence from repository construction: 2005 to 2009 (millions of dollars).[a]

Jurisdiction	2005	2006	2007	2008	2009
Clark County					
Disposable income	54	100	103	85	77
Gross Regional Product	80	142	136	100	73
State and local government expenditures	1.5	4.8	7.6	9.1	9.9
Nye County					
Disposable income	3.7	6.7	6.8	5.7	5.9
Gross Regional Product	10	19	18	15	12
State and local government expenditures	0.2	0.5	0.9	1	1.3
Lincoln County					
Disposable income	0.1	0.3	0.3	0.2	0.2
Gross Regional Product	0.1	0.2	0.2	0.2	0.1
State and local government expenditures	0	0	0.1	0.1	0.1
Total region of influence[b]					
Disposable income	58	108	110	90	83
Gross Regional Product	90	160	155	115	85
State and local government expenditures	1.7	5.3	8.5	10	11

a. Numbers are expressed in 2001 dollars.
b. Totals might differ from sums of values due to rounding.

Table 4-20. Increases in economic measures within the region of influence from emplacement and development activities: 2010 to 2033 (millions of dollars).[a]

Jurisdiction	2010	2015	2020	2025	2030	2033
Clark County						
Disposable income	97	104	119	129	133	110
Gross Regional Product	90	82	96	106	105	69
State and local government expenditures	11	15	16.7	18	13	17
Nye County						
Disposable income	8.2	11	13	14	15	14
Gross Regional Product	15	15	16	17	17	12
State and local government expenditures	1.6	2.6	3.2	3.5	3.7	3.6
Lincoln County						
Disposable income	0.3	0.3	0.3	0.4	0.4	0.3
Gross Regional Product	0.2	0.2	0.2	0.2	0.2	0.2
State and local government expenditures	0.1	0.1	0.1	0.1	0.1	0.1
Total region of influence[b]						
Disposable income	106	115	132	144	149	124
Gross Regional Product	104	97	113	123	122	81
State and local government expenditures	12	18	20	21	22	21

a. Numbers are expressed in 2001 dollars.
b. Totals might differ from sums of values due to rounding.

The impact to housing would be minimal because (a) the expected increase in population is so small, (b) the demand is expected to be concentrated in a metropolitan area (Clark County), (c) there are no municipal or state growth control measures that limit housing development, and (d) the region of influence has an adequate supply of undeveloped land to meet expected future demands. Southern Nye County, particularly Pahrump, would experience some demand for housing. In Lincoln County, little or no demand for housing resulting from repository activities would be likely, so housing availability would not be an issue.

During the 1990s and early 21st century, the Bureau of Land Management has conducted land exchanges in Nevada. These exchanges have typically involved a trade of environmentally sensitive land outside Clark County for Bureau land in the County. The land in Clark County moves to the private sector for

Main Index Vol 1 Index

sale to land developers, particularly developers of large master-planned, densely occupied communities. The land swap policy has helped to accommodate population growth in the greater Las Vegas area.

4.1.6.2.5 Impacts to Public Services

Repository-generated impacts to public services from population changes in the region of influence would be small. Population changes in the region from the maximum repository-related employment case would be a small fraction of the anticipated population growth in the region. Even without the addition of repository jobs, the annual regional growth rate would increase by an estimated 2 to 4 percent, minimizing a possible need to alter plans already in place to meet projected growth.

As mentioned above, the majority of inmigrating workers would likely live in the many communities of Clark County, thereby dispersing the increased demand for public services, including schools. Southern Nye County, particularly Pahrump, also would experience an increased demand for public services. However, because the changes in population (about 1,100 residents in the peak year) would occur steadily over a long period, the County would be able to absorb increased demands in education, law enforcement, and fire protection. Repository-generated impacts to public services would be unlikely in Lincoln County.

4.1.6.3 Summary of Socioeconomic Impacts

The potential socioeconomic impacts associated with repository activities are summarized in this section. For all five socioeconomic parameters evaluated over construction, operations, and decontamination activities, the impacts would be very small, less than 1 percent of the baselines for the region of influence. The construction phase would experience greater impacts for employment, Gross Regional Product, and real disposable income. The operations and decontamination activities would cause the greater impact from increases in population and government spending.

The lower-temperature operating mode and the higher-temperature operating mode would have similar potential impacts. Composite employment, which includes workers directly associated with the construction activity and other indirect workers (food service providers and auto mechanics for example), would peak in 2006. The increase of 3,400 workers represents a 0.36 percent increase to the expected baseline. Gross Regional Product would also peak in 2006 as various goods and services associated with the construction activities were consumed. The expected increase in Gross Regional Product for 2006 is about $160 million, (all values for economic parameters are expressed in 2001 dollars) or 0.31 percent of the baseline. Peak years for the other socioeconomic impacts would be delayed until the operations period. Population increases caused by the increased employment opportunities would peak in 2030, at about 6,200 or less than 0.25 of a percent of the baseline for the year. Government spending would peak in 2030 at $22 million or 0.22 percent of the baseline. Disposable income would also be highest during the operations period, peaking in 2029 at $149 million, or 0.23 percent of the baseline. Impacts during the subsequent decontamination activities, monitoring period, and closure phase would be similar to or smaller than the impacts summarized above.

4.1.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY IMPACTS

This section describes potential health and safety impacts to workers (occupational impacts) and to members of the public from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. The analysis estimated health and safety impacts separately for involved workers and noninvolved workers for each repository phase. Involved workers are craft and operations personnel who would be directly involved in the activities related to facility construction and operations, including excavation activities; receipt, handling, packaging, aging, and emplacement of spent nuclear fuel and high-level radioactive waste materials; maintenance of the solar power facility; monitoring of the condition and performance of the waste packages; and eventual closure of the repository. Noninvolved workers are managerial, technical, supervisory, and administrative personnel who would not be directly involved in the above activities. This section describes impacts from the receipt of uncanistered spent nuclear fuel. Impacts for canistered fuel would be smaller, as reported in Appendix F, Section F.2.

The types of potential health and safety impacts to repository workers include those from industrial hazards common to the workplace, those from exposure to naturally occurring and manmade radiation and radioactive materials present in the workplace, and those from exposure to naturally occurring nonradioactive airborne hazardous material. Members of the public could be exposed to airborne releases of naturally occurring and manmade radionuclides and naturally occurring hazardous materials. Estimates of human health impacts to members of the public are based on information presented in Section 4.1.2.

Appendix F describes the methodology, data, and data sources used for the calculations of health and safety impacts to workers and supporting detailed results. It also contains a human health impacts primer.

4.1.7.1 Impacts to Occupational and Public Health and Safety from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities would be similar to the activities performed during Yucca Mountain site characterization. Their purpose would be to ensure that systems, operations, and materials were functioning as predicted. These activities could include the construction of surface facilities to support performance confirmation, excavation of exploratory tunnels, and testing and monitoring activities in the drifts. Chapter 3 describes site characterization activities and the resulting affected environment.

Potential health and safety impacts that could occur during preconstruction testing and performance confirmation activities include those common to an industrial work setting, radiological impacts to the public and workers from exposure to radon-222 and its decay products, external radiation exposure of workers in the subsurface environment, and the potential for exposure to naturally occurring hazardous materials generated by excavation activities. Section 4.1.7.2 contains additional information on these potential exposure pathways. No spent nuclear fuel and high-level radioactive waste would be present during preconstruction testing and performance confirmation activities, so radiation exposure of workers from this source would not occur.

Impacts are likely to be very small during preconstruction testing and performance confirmation activities. Incremental health and safety impacts to workers for the performance confirmation period would be less than 2 percent of those estimated for the construction, operation and monitoring, and closure phases, based on comparisons of worker activities and the number of worker-years between site characterization (DIRS 104957-DOE 1994, all) and repository activities (see Appendix F). Potential radiological impacts to members of the public would be less than those estimated for the construction phase (Section 4.1.7.2). The probability of latent cancer fatality in the offsite maximally exposed individual would be about 0.0000002. No latent cancer fatalities (less than 0.004) would be likely in the potentially exposed population.

4.1.7.2 Impacts to Occupational and Public Health and Safety from Initial Construction

This section describes estimates of health and safety impacts to repository workers and members of the public for the 5-year initial construction phase. During this phase, DOE would build the surface facilities, excavate the main drifts, and excavate enough emplacement drifts to support initial emplacement activities. Potential health and safety impacts to workers would occur from industrial hazards, exposure to naturally occurring radionuclides, and exposure to naturally occurring cristobalite and erionite in the rock at the Yucca Mountain site. Potential health impacts to members of the public would be from exposure to airborne releases of naturally occurring radionuclides and hazardous materials.

4.1.7.2.1 *Occupational Health and Safety Impacts*

Industrial Hazards. The analysis estimated health and safety impacts to workers from hazards common to the industrial setting in which they would be working using statistics for similar kinds of operations in the DOE complex and estimates of the total number of full-time equivalent worker years that would be involved in the activity. The statistics that the analysis used are from the DOE Computerized Accident/Incident Reporting and Recordkeeping System (DIRS 147938-DOE 1999, all). These statistics reflect recent DOE experience for these types of activities. Appendix F, Section F.2.2.2, contains more information on the selection of impact statistics.

Estimates of impacts were based on the number of full-time worker years during the construction phase for the repository operating modes. Table 4-21 lists the estimated impacts to workers from industrial hazards for the repository construction phase. The table lists impacts for three types of industrial safety impacts; total recordable cases of injuries and illnesses that are work-related, total lost workday cases, and fatalities (see the discussion in Appendix F, Section F.2.2).

Table 4-21. Impacts to workers from industrial hazards during initial construction phase.[a,b]

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature
Involved workers		
Total recordable cases	340	340 - 370
Lost workday cases	160	160 - 180
Fatalities	0.16	0.16 - 0.18
Noninvolved workers		
Total recordable cases	55	55 - 61
Lost workday cases	27	27 - 30
Fatalities	0.048	0.048 - 0.054
All workers (totals)[c]		
Total recordable cases	400	400 - 430
Lost workday cases	190	190 - 210
Fatalities	0.21	0.21 - 0.23

a. Source: Appendix F, Table F-12. Numbers are rounded to two significant figures.
b. The analysis assumed that the construction phase would last 44 months for surface facility construction and 60 months for subsurface construction activities.
c. Totals might differ from sums of values due to rounding.

No worker fatalities would be expected during construction for any of the operating modes. For the higher-temperature operating mode, the estimated fatalities are 0.21. The range for the lower-temperature operating mode is 0.21 to 0.23 fatality.

Naturally Occurring Hazardous Materials. Two types of naturally occurring hazardous materials could be encountered by workers at the Yucca Mountain site—cristobalite, a form of crystalline silica (silicon dioxide, SiO_2), and erionite, a naturally occurring zeolite. Both are present in the subsurface rock at Yucca Mountain and have the potential to become airborne during repository excavation and activities involving excavated rock and would be released during tunneling operations. It could also be released with dust from the excavated rock pile. Erionite is a natural zeolite that occurs in the rock layers below the proposed repository level (see Chapter 3, Section 3.1.3). It might also occur in rock layers above the repository level but activities to date have not found it in those layers. Erionite could become a hazard during vertical boring operations if the operations passed through a rock layer containing erionite (which would be unlikely), and during excavation for access to the lower block. Additional information on the potential hazards of these naturally-occurring materials is found in Appendix F, Section F.1.2.

Cristobalite is present in the welded tuff at the repository level and would become airborne in the repository environment during excavation and rock moving activities. The welded tuff has an average cristobalite content of between 18 and 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81).

DOE would use engineering controls during subsurface work to control exposures of workers to silica dust. Water would be applied during excavation activities to wet both the rock face and the broken rock to minimize airborne dust levels. Wet or dry dust scrubbers would capture dust that the water sprays did not suppress. The fresh air intake and the exhaust air streams would be separated to prevent increased dust concentrations in the drift atmosphere from recirculation. In addition, the ventilation system would be designed and operated to control ambient air velocities to minimize dust resuspension. DOE would monitor the working environment to ensure that workers were not exposed to dust concentrations higher than the applicable limits for cristobalite. If engineering controls were unable to maintain dust concentrations below the limits, administrative controls such as access restrictions or respiratory protection would be used until the engineering controls could establish acceptable conditions. Similar controls would be applied, if required, for surface workers. DOE expects that exposure of workers to silica dust would be below the applicable limits and potential impacts to subsurface and surface workers would be very small.

DOE does not expect to encounter erionite layers either during vertical boring operations (which would be through rock layers above known erionite layers) or during excavation to provide access to the lower block and offset areas. Access excavation would be planned to avoid any identified layers of erionite (DIRS 104532-McKenzie 1998, all). If erionite was encountered during excavation for access to the lower block or during vertical boring operations, the engineering controls described above for cristobalite would be instituted and, if necessary, administrative controls would be used until acceptable conditions were reestablished.

Radiological Health Impacts. Spent nuclear fuel and high-level radioactive waste would not be present at the repository site during the construction phase and so would not contribute to radiological impacts. Potential radiological health impacts to involved and noninvolved workers in subsurface facilities during the initial construction phase would be from two sources: inhalation of naturally occurring radon-222 and its decay products following emanation of the radon from the surrounding rock, and external radiation dose from naturally occurring radionuclides in the drift walls, principally potassium-40 and radionuclides in the uranium decay series (DIRS 104544-CRWMS M&O 1999, Sections 4 and 5). Radon-222 is a noble gas of the uranium-238 decay series. Because it is a noble gas, radon emanates from the rock into the drifts, where elevated concentrations of radon-222 and its decay products could occur in the repository atmosphere (see Chapter 3, Section 3.1.8.2). Workers in surface facilities and members of the public would also be exposed to naturally occurring radon-222 and decay products as these radionuclides would be released from the subsurface in exhaust ventilation air. Section 4.1.2.2.2 provides more detailed discussion of these airborne release exposures.

Measurements in the Exploratory Studies Facility indicated an underground ambient external dose rate from radionuclides in the drift walls of about 50 millirem per work year of 2,000 hours underground. This is slightly higher than the dose rate from the cosmic and cosmogenic components of natural background radiation on the surface of about 40 millirem per year in the Amargosa Valley region (see Section 3.1.8.2). This analysis considers the underground ambient external radiation dose to be part of the involved worker occupational dose.

Table 4-22 lists estimated potential doses and radiological health impacts for the construction phase to involved workers, noninvolved workers, and the total for all workers. It includes estimated doses and

Main Index Vol 1 Index

Table 4-22. Radiation dose and radiological health impacts to workers during the initial construction phase.[a,b,c]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Maximally exposed worker		
Dose, rem		
Involved	1.3	1.3
Noninvolved	0.33	0.33
Probability of latent cancer fatality		
Involved	0.00052	0.00052
Noninvolved	0.00013	0.00013
Worker population		
Collective dose (person-rem)		
Involved	680	680
Noninvolved	37	37
Total[d]	720	720
Number of latent cancer fatalities		
Involved	0.27	0.27
Noninvolved	0.015	0.015
Total[d]	**0.29**	**0.29**

a. Numbers are rounded to two significant figures.
b. Source: Appendix F, Table F-11.
c. Only subsurface workers have potential for measurable radiation dose (from natural sources) during the initial construction phase.
d. Totals might differ from sums of values due to rounding.

radiological health impacts for the maximally exposed involved worker and for the involved worker population; radiological health impacts for the maximally exposed noninvolved worker and for the noninvolved worker population; and the estimated collective dose and radiological health impacts for the combined population of workers. Estimated doses were converted to estimates of latent cancer fatalities using a dose-to-risk conversion factor of 0.0004 latent cancer fatality per rem (see Appendix F, Section F.1.1.5). Radiological health impacts for maximally exposed individuals are presented as the increase in the probability of a latent cancer fatality resulting from the radiation dose received. Radiological health impacts for exposed populations are presented as the number of latent cancer fatalities estimated to result from the collective radiation dose received.

During the initial construction phase the only source of radiation would be from naturally occurring radionuclides in the subsurface, so radiological health impacts to the surface facility workforce would be much lower than those to the subsurface facility workforce. Values presented in Table 4-22 are those for subsurface workers (see Appendix F, Table F-11).

The estimated increase in the number of latent cancer fatalities for workers would be low (about 0.3); the estimated increase in the likelihood that an individual worker would die from a latent cancer fatality would also be small (about 0.0005).

4.1.7.2.2 *Public Health Impacts*

Naturally Occurring Hazardous Materials. Section 4.1.2.2.1 presents estimated annual average concentrations of cristobalite at the *site boundary* where members of the public could be exposed during the construction phase. The analysis estimated concentrations of about 0.02 microgram per cubic meter for the operating modes, and health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public during the construction phase would come from exposure to airborne releases of naturally occurring radon-222 and its decay products in the subsurface exhaust ventilation air. Estimates of radiation doses for the offsite maximally exposed individual and the potentially exposed population are presented in Section 4.1.2.2.2. The offsite maximally exposed individual is a hypothetical member of the public at a point on the land withdrawal boundary that would receive the highest radiation dose and resultant radiological health impact. This location would be at the southern boundary of the land withdrawal area. The exposed population is that within 80 kilometers (50 miles) of the repository (see Section 3.1.8). Estimated doses to members of the public were converted to estimates of latent cancer fatalities using a dose-to-risk conversion factor of 0.0005 latent cancer fatality per rem for members of the public (see Appendix F, Section F.1.1.5).

Table 4-23 lists the estimated doses and radiological health impacts to members of the public from the 5-year initial construction phase. The radiological health impacts to the public from repository construction would be very small (with 0.02 latent cancer fatality or less estimated for all of the operating modes). The estimated individual risk of contracting a latent cancer fatality for the maximally exposed individual would be 0.000001 or less over the 5-year phase.

Table 4-23. Radiation doses and radiological health impacts to the public during the initial construction phase.[a,b,c]

	Operating mode			
	Entire phase		Maximum annual	
Dose and health impact	Higher-temperature	Lower-temperature	Higher - temperature	Lower-temperature
Maximally exposed individual[d]				
Dose (millirem)	1.7	1.7 - 2.0	0.43	0.43 - 0.53
Latent cancer fatality probability	8.5×10^{-7}	$0.85 - 1.0 \times 10^{-6}$	2.1×10^{-7}	$2.1 - 2.6 \times 10^{-7}$
Exposed 80-km population[e]				
Collective dose (person-rem)	33	33 - 40	8.4	8.4 - 10
Number of latent cancer fatality	0.017	0.017 - 0.020	0.0042	0.0042 - 0.0052

a. Numbers are rounded to two significant figures.
b. Source: Table 4-2.
c. All of the dose and impact are from naturally occurring radon-222 and decay products.
d. Located at the southern boundary of the land withdrawal area.
e. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

4.1.7.3 Occupational and Public Health and Safety Impacts from Operation and Monitoring

This section describes possible health and safety impacts to workers and members of the public for the operation and monitoring phase. This phase has two main components: the operations period (including continuing subsurface development) and the monitoring period. The overall phase length would range from 100 years for the higher-temperature operating mode up to 324 years for the lower-temperature operating mode. Impacts of the operations period and the monitoring period are described below.

4.1.7.3.1 *Operations Period – Handling, Emplacement, and Continuing Development*

This period would consist of a 24-year period for operations, including the receipt, handling, packaging, possible aging, and emplacement of spent nuclear fuel and high-level radioactive waste. There would be a concurrent (except for the last two years) 22-year period for continued construction (development) of underground repository features, including access drifts, emplacement drifts, shafts, and so on. Where aging of commercial spent nuclear fuel could occur under the lower temperature operating mode an additional 26 years of emplacement and handling would be needed, for a total operations period length of 50 years.

4.1.7.3.1.1 Occupational Impacts

Industrial Hazards. Table 4-24 summarizes health and safety impacts from common industrial hazards for the operations period. Impacts were estimated separately for surface operations, subsurface emplacement operations, and subsurface drift development operations, then were summed to develop these results.

Table 4-24. Impacts to workers from industrial hazards during the operations period.[a]

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature
Involved workers		
Total recordable cases	1,200	1,200 - 1,700
Lost work day cases	590	620 - 840
Fatalities	0.90	0.91 - 1.4
Noninvolved workers		
Total recordable cases	300	310 - 470
Lost workday cases	150	150 - 230
Fatalities	0.31	0.31 - 0.45
All workers (totals)[b]		
Total recordable cases	1,500	1,500 - 2,200
Lost workday cases	740	770 - 1,100
Fatalities	1.2	1.2 - 1.9

a. Values taken from Appendix F, Table F-22.
b. Totals might differ from sums of values due to rounding.

About 1.2 fatalities were estimated for the higher-temperature operating mode, with a range of 1.2 to 1.9 fatalities estimated for the lower-temperature operating mode. The highest estimates would be where aging would be used (longer operations period, more worker-years) with maximum spacing of the waste packages, which results in the largest repository and thus more excavation.

Naturally Occurring Hazardous Material. As discussed in Section 4.1.7.2.1 for the construction phase, DOE would use engineering controls and, if necessary, administrative worker protection measures to control and minimize impacts to workers from releases of cristobalite and erionite during the operations period. Controls would be necessary mainly for continuing development activities underground but also for activities associated with the excavated rock pile. As for the construction phase, impacts would be expected to be very small.

Radiological Health Impacts. Occupational radiological health impacts during the operations period would be a combination of impacts to surface workers during handling operations, and impacts to subsurface workers during development and emplacement operations. These impacts are presented in Table 4-25.

The estimated radiological health impacts to the worker population for the 24 or 50-year operations period would range from 3.1 to 4.8 latent cancer fatalities. Estimated radiological health impacts to the maximally exposed individual would range from 15 to 30 rem, with a corresponding probability of latent cancer fatality ranging from 0.0060 to 0.012. The principal contributors to radiological health impacts would be surface facility operations, which would involve the receipt, handling, and packaging of spent nuclear fuel and high-level radioactive waste for emplacement and subsurface monitoring activities.

Table 4-25. Radiation dose and radiological health impacts to workers during the operations period.[a,b]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Maximally exposed worker		
Dose, rem		
Involved	15	15 - 30
Noninvolved	1.5	1.5 - 1.8
Probability of latent cancer fatality		
Involved	0.0060	0.0060 - 0.012
Noninvolved	0.00060	0.00060 - 0.00072
Worker population		
Collective dose (person-rem)		
Involved	7,500	7,600 - 12,000
Noninvolved	150	160 - 170
Total[c]	**7,700**	**7,800 - 12,000**
Number of latent cancer fatalities		
Involved	3.0	3.0 - 4.8
Noninvolved	0.060	0.064 - 0.068
Total[c]	**3.1**	**3.1 - 4.8**

a. Numbers are rounded to two significant figures.
b. Source: Appendix F, Table F-23.
c. Totals might differ from sums of values due to rounding.

DOE would consider the inspection, testing, or retrieval of a waste package that had already been emplaced to be an off-normal condition of routine operations that it has already considered (see Chapter 2, Section 2.1.2.2.3). Any such operation would be carried out under the repository radiation protection program, and worker dose limits would apply. Therefore, any radiation dose from such an operation would already be included in the estimated doses to the maximally exposed workers and worker populations listed in Table 4-25.

4.1.7.3.1.2 Public Health Impacts

Naturally Occurring Hazardous Materials. Section 4.1.2.3.1 presents estimated annual average concentrations of cristobalite at the land withdrawal boundary where members of the public could be exposed during the operation and monitoring phase. The analysis estimated annual average concentrations of about 0.009 to 0.017 microgram per cubic meter for the operating modes. Health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower than for cristobalite at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public from operations period activities could result from exposure to naturally occurring radon-222 and its decay products released in subsurface exhaust ventilation air, and from exposure to radioactive noble gas fission products, principally krypton-85, that could be released from the Waste Handling Building during spent nuclear fuel handling operations. Krypton-85 and other noble gas fission products would be very small contributors to dose and potential radiological impacts, less than 0.01 percent of the dose from radon-222 and its decay products (see Section 4.1.2.3.2).

Section 4.1.2.3.2 presents estimates of dose to the public for the handling, emplacement, and continuing development (operations) period. Table 4-26 presents these doses and the potential radiological health impacts to the public for that period. Potential radiological health impacts would be very small. The probability of a latent cancer fatality occurring in the maximally exposed individual would be 0.000022 or less. The number of latent cancer fatalities estimated to occur in the exposed population would range from 0.012 to 0.42.

Main Index Vol 1 Index

Table 4-26. Radiation doses and radiological health impacts to the public during the operations period.[a,b,c,d]

	Operating mode			
	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Dose and health impact	Entire period		Maximum annual	
Maximally exposed individual[e]				
Dose (millirem)	12	17 - 43	0.73	1.0 - 1.3
Latent cancer fatality probability	6.0×10^{-6}	$0.83 - 2.2 \times 10^{-5}$	3.7×10^{-7}	$5.2 - 6.7 \times 10^{-7}$
Exposed 80-km population[f]				
Collective dose (person-rem)	230	320 - 830	14	20 - 26
Number of latent cancer fatality	0.12	0.16 - 0.42	0.0071	0.010 - 0.013

a. Numbers are rounded to two significant figures.
b. Source: Table 4-4.
c. Greater than 99.9 percent of the dose would be from naturally occurring radon-222 and decay products.
d. Fuel handling activities during the operation and monitoring phase would last 24 years. Emplacement activities would last 24 years with no aging, and 50 years with aging. Continued subsurface development activities would last 22 years.
e. Individual located at the southern boundary of the land withdrawal area for all of the operations period (24 or 50 years).
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).

4.1.7.3.2 *Monitoring Period*

This period would last 76 years under the higher-temperature operating mode and up to 300 years under lower-temperature operating modes. The first 3 years of this period would include decontamination of surface fuel handling facilities in preparation for the long periods of monitoring and maintenance to follow, and ultimately for closure. Only monitoring and maintenance activities would take place during the remainder of the period, including periodic replacement of the solar facility components. Most of the potential operating modes would include active ventilation during this period, but 250 years of natural ventilation could be used, during which there would be lower ventilation flow rates (see Section 2.1.1.2.2).

4.1.7.3.2.1 Occupational Impacts

Industrial Hazards. Table 4-27 lists health and safety impacts from common industrial hazards for the monitoring period, including decontamination activities. Impacts were estimated separately for the surface facility decontamination operations, surface operations to support subsurface monitoring, and subsurface monitoring itself.

About 0.4 fatality would be expected to occur for the higher-temperature operating mode. The range of fatalities predicted for the lower-temperature operating mode is 0.44 to 1.1 fatalities with the largest value for long-term ventilation with aging of the spent nuclear fuel.

Naturally Occurring Hazardous Material. During monitoring and maintenance activities there would be little opportunity for large quantities of dust to be generated for extended periods of time. If necessary, and as discussed in Section 4.1.7.2.1 for the construction phase, DOE would use engineering controls and, if necessary, administrative worker protection measures such as respiratory protection to control and minimize impacts to workers from releases of cristobalite and erionite during monitoring activities.

Radiological Health Impacts. Occupational radiological health impacts during the monitoring period would be a combination of impacts to surface workers during facility decontamination and subsurface workers during monitoring and maintenance activities. These impacts are presented in Table 4-28.

Table 4-27. Impacts to workers from industrial hazards during the monitoring period.[a,b]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Involved workers		
Total recordable cases	320	400 - 1,000
Lost work day cases	130	160 - 410
Fatalities	0.31	0.38 - 1.0
Noninvolved workers		
Total recordable cases	55	65 - 150
Lost workday cases	27	32 - 73
Fatalities	0.049	0.057 - 0.13
All workers (totals)[c]		
Total recordable cases	380	470 - 1,200
Lost workday cases	160	190 - 480
Fatalities	0.36	0.44 - 1.1

a. Values are rounded to two significant figures.
b. Source: Appendix F, Table F-31.
c. Totals might differ from sums of values due to rounding.

Table 4-28. Radiation dose and radiological health impacts to workers during the monitoring period.[a,b]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Maximally exposed worker[c]		
Dose, rem		
Involved	18	18
Noninvolved	1.8	1.8
Probability of latent cancer fatality		
Involved	0.0072	0.0072
Noninvolved	0.00072	0.00072
Worker population		
Collective dose (person-rem)		
Involved	1,100	1,500 - 4,300
Noninvolved	36	46 - 140
Total[d]	**1,100**	**1,500 - 4,400**
Number of latent cancer fatalities		
Involved	0.44	0.60 - 1.7
Noninvolved	0.014	0.018 - 0.056
Total[d]	**0.44**	**0.60 - 1.8**

a. Numbers are rounded to two significant figures.
b. Source: Appendix F, Table F-32.
c. Maximally exposed worker is a subsurface involved worker who works in the subsurface environment for 50 years.
d. Totals might differ from sums of values due to rounding.

The estimated radiological health impacts to the worker population for the 76- to 300-year monitoring period would range from 0.44 to 1.8 latent cancer fatalities. The relatively wide range in impacts is due mainly to the differences in the length of the monitoring periods. Estimated radiological health impacts to the maximally exposed individual would be 18 rem for the range of operating modes, with a corresponding probability of latent cancer fatality of 0.0072. Estimated doses and radiological health impacts to the maximally exposed worker are based on a 50-year working lifetime. The principal contributor to radiological health impacts would be from subsurface facility monitoring and maintenance activities.

4.1.7.3.2.2 Public Health Impacts

Naturally Occurring Hazardous Materials. Section 4.1.2.3.1 presents estimated annual average concentrations of cristobalite at the land withdrawal boundary where members of the public could be exposed during the operation and monitoring phase. The analysis estimated annual average concentrations of 0.009 to 0.017 microgram per cubic meter; however, these concentrations are likely more representative of operations period activities while those during the monitoring period would be even lower. Health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower than for cristobalite at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public from monitoring period activities would result from exposure to naturally occurring radon-222 and its decay products released in subsurface exhaust ventilation air. No releases of radioactive material or radiation dose to the public are anticipated for decontamination activities (DIRS 152010-CRWMS M&O 2000, pp. 55-56).

Section 4.1.2.3.2 presents estimates of dose to the public for the monitoring period. Table 4-29 lists these doses and potential radiological health impacts to the public for that period. Potential radiological health impacts would be low. The probability of a latent cancer fatality occurring in the maximally exposed individual would be 0.000031 or less. The number of latent cancer fatalities estimated to occur in the exposed population would range from 0.75 to 1.7. Because of the length of the monitoring period compared to other project periods, most of the estimated radiological impacts to the public would occur during this period.

Table 4-29. Radiation doses and radiological health impacts to the public during the monitoring period.[a,b,c,d]

	Operating mode			
	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Dose and health impact	Entire period		Maximum annual	
Maximally exposed individual[e]				
Dose (millirem)	29	30 - 62	0.41	0.59 - 0.89
Latent cancer fatality probability	1.5×10^{-5}	$1.5 - 3.1 \times 10^{-5}$	2.1×10^{-7}	$3 - 4.4 \times 10^{-7}$
Exposed 80-kilometer population[f]				
Collective dose (person-rem)	600	1,500 - 3,500	8	11 - 17
Number of latent cancer fatalities	0.31	0.75 - 1.7	0.004	0.0057 - 0.0085

a. Numbers are rounded to two significant figures.
b. Source: Table 4-5.
c. All dose would be from naturally occurring radon-222 and decay products.
d. Monitoring and maintenance period would last from 76 to 300 years.
e. Individual located at the southern boundary of the land withdrawal area for 10 years.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

4.1.7.4 Impacts to Occupational and Public Health and Safety from Closure

This section contains estimates of health and safety impacts to workers and to members of the public for the closure phase. The length of this phase depends on the operating mode. The higher-temperature operating mode closure phase would last 10 years, while closure for the lower-temperature operating mode would range from 11 to 17 years in length.

Main Index Vol 1 Index

4.1.7.4.1 *Occupational Impacts*

Industrial Hazards. Table 4-30 lists impacts to workers from normal industrial workplace hazards for the closure phase. No workplace industrial fatalities (0.2 to 0.25) would be expected during closure. The range of impacts is due to the differences in the length of the closure period, because closure activities are similar under all operating modes.

Table 4-30. Impacts to workers from industrial hazards during the closure phase.[a,b]

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature
Involved workers		
Total recordable cases	320	340 - 420
Lost work day cases	150	160 - 200
Fatalities	0.15	0.16 - 0.2
Noninvolved workers		
Total recordable cases	51	53 - 62
Lost workday cases	25	26 - 30
Fatalities	0.045	0.047 - 0.054
All workers (totals)[c]		
Total recordable cases	370	390 - 480
Lost workday cases	180	190 - 230
Fatalities	0.2	0.21 - 0.25

a. Values are rounded to two significant figures.
b. Source: Appendix F, Table F-38.
c. Totals might differ from sums of values due to rounding.

Naturally Occurring Hazardous Material. During closure activities there would be potential for dust to be generated (for example, during preparation and emplacement of excavated rock for backfill). The potential for dust generation, especially in the underground environment, would be less than for subsurface excavation during the construction phase and operations period. As necessary, DOE would use engineering controls and worker protection measures such as those discussed in Section 4.1.7.2.1 for the construction phase to control and minimize potential impacts to workers. Potential impacts would be very small.

Radiological Health Impacts. During the closure phase, subsurface workers would be exposed to radon-222 in the drift atmosphere, to external radiation from radionuclides in the drift walls, and to external radiation from the waste packages. Table 4-31 lists radiological impacts to workers for the closure phase. There is low potential for exposure of surface workers, and most of the radiation dose and potential radiological health impacts would be to subsurface workers. The maximally exposed worker would be a subsurface worker. The estimated radiological health impacts to the worker population for the 10 to 17 year closure phase would range from 0.15 to 0.28 latent cancer fatality. The range in impacts is due mainly to the differences in the length of the phase for the range of operating modes. Estimated radiological health impacts to the maximally exposed individual would range from 6.7 to 13 rem, with a corresponding probability of latent cancer fatality ranging from 0.0027 to 0.0052. The principal sources of exposure to subsurface workers would be from inhalation of radon-222 and its decay products.

4.1.7.4.2 *Public Health Impacts*

Naturally Occurring Hazardous Material. Section 4.1.2.4.1 presents estimated annual average concentrations of cristobalite during the closure phase at the land withdrawal boundary, where members of the public could be exposed. There would be no subsurface excavation during the closure phase, so cristobalite concentrations would be less than for earlier phases. Annual average concentrations of about 0.012 to 0.013 microgram per cubic meter were estimated for the operating modes, and health impacts to

Table 4-31. Radiation dose and radiological health impacts to workers during closure phase.[a,b,c]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Maximally exposed worker[d]		
Dose, rem		
Involved	6.7	7.9 - 13
Noninvolved	0.36	0.40 - 0.61
Probability of latent cancer fatality		
Involved	0.0027	0.0032 - 0.0052
Noninvolved	0.00014	0.00016 - 0.00024
Worker population		
Collective dose (person-rem)		
Involved	430	480 - 740
Noninvolved	16	18 - 28
Total[e]	450	500 - 770
Number of latent cancer fatalities		
Involved	0.17	0.19 - 0.30
Noninvolved	0.0064	0.0072 - 0.011
Total[e]	***0.18***	***0.2 - 0.31***

a. Numbers are rounded to two significant figures.
b. Source: Appendix F, Table F-39.
c. Closure phase would last 10 to 17 years.
d. The maximally exposed individual would be a subsurface worker.
e. Totals might differ from sums of values due to rounding.

the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure. Potential impacts would be very small.

Radiological Health Impacts. Potential radiation-related health impacts to the public from closure activities would result from exposure to radon-222 and its decay products released in the subsurface exhaust ventilation air. Section 4.1.2.4.2 presents estimates of dose to the public for the closure phase. Table 4-32 lists the estimated dose and radiological health impacts.

Table 4-32. Radiation dose and radiological health impacts to public for the closure phase.[a,b,c,d]

	Operating mode			
	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Dose and health impact	Entire phase		Maximum annual	
Maximally exposed individual[e]				
Dose (millirem)	3	4.3 - 9.4	0.4	0.57 - 0.87
Latent cancer fatality probability	1.5×10^{-6}	$2.2 - 4.7 \times 10^{-6}$	2.0×10^{-7}	$2.8 - 4.3 \times 10^{-7}$
Exposed 80-km population[f]				
Collective dose (person-rem)	57	83 - 180	7.4	10 - 16
Number of latent cancer fatality	0.028	0.041 - 0.090	0.0037	0.0052 - 0.0081

a. Numbers are rounded to two significant figures.
b. Source: Table 4-7.
c. All dose would be from naturally occurring radon-222 and decay products.
d. The closure phase would last from 10 to 17 years.
e. Individual located at the southern boundary of the land withdrawal area.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

Potential radiological health impacts would be small. The probability of a latent cancer fatality occurring in the maximally exposed individual would be 0.0000047 or less. The number of latent cancer fatalities estimated to occur in the exposed population would range from 0.028 to 0.090. Differences in potential impacts are due mainly to differences in the length of the closure phase.

4.1.7.5 Total Impacts to Occupational and Public Health and Safety for All Phases

This section presents estimates of the total human health and safety impacts to workers and members of the public from proposed activities at the Yucca Mountain repository. It describes the total impacts from activities during the construction, operation and monitoring, and closure phases to workers from industrial hazards and radiation exposure, and to members of the public from radiation exposure.

Among other operating factors, total project impacts would depend on the duration of the project. The higher-temperature operating mode would last 115 years, while the lower-temperature operating mode would last from 171 to 341 years. These time periods include a 5-year construction phase and variable time periods for the operation and monitoring phase (100 to 324 years) and closure phase (10 to 17 years), as discussed in the previous sections. In general, the highest potential health and safety impacts would occur during the operation and monitoring phase.

4.1.7.5.1 *Total Impacts to Workers from Industrial Hazards for All Phases*

Total impacts to workers from industrial hazards for the entire project are shown in Table 4-33. The estimated number of workplace fatalities would range from 2.0 for the higher-temperature operating mode to 3.3 for the upper end of the lower-temperature operating mode.

Table 4-33. Total impacts to workers from industrial hazards for all phases.[a]

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature[b]
Involved workers		
Total recordable cases	2,200	2,500 - 3,300
Lost work day cases	1,000	1,200 - 1,500
Fatalities	1.5	1.8 - 2.6
Noninvolved workers		
Total recordable cases	460	500 - 720
Lost workday cases	230	250 - 350
Fatalities	0.45	0.48 - 0.68
All workers (totals[c,d])		
Total recordable cases	2,700	3,000 - 4,000
Lost workday cases	1,300	1,500 - 1,900
Fatalities	2.0	2.3 - 3.3

a. Numbers are rounded to two significant figures.
b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
c. Source: Tables 4-21, 4-24, 4-27, and 4-30.
d. Totals might differ from sums of values due to rounding.

4.1.7.5.2 *Total Radiological Health Impacts to Workers for All Phases*

Total radiation dose and radiological health impacts to workers for the entire project (all phases) are listed in Table 4-34. Dose and impact for the maximally exposed individual worker are listed for a 50-year working lifetime. The collective dose to the worker population and potential radiological health impacts are shown for the entire project duration, ranging from 115 years for the higher-temperature operating mode up to 341 years for the lower-temperature operating mode.

Table 4-34. Total radiation dose and radiological health impacts to workers for all phases.[a,b]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Maximally exposed worker[d]		
Dose, rem		
Involved	18	18 - 30
Noninvolved	1.8	1.8
Probability of latent cancer fatality		
Involved	0.0072	0.0072 - 0.012
Noninvolved	0.00072	0.00072
Worker population		
Collective dose (person-rem)		
Involved	9,700	11,000 - 17,000
Noninvolved	240	280 - 360
Total[e]	**10,000**	**11,000 - 17,000**
Number of latent cancer fatalities		
Involved	3.9	4.4 - 6.8
Noninvolved	0.092	0.11 - 0.14
Total[e]	**4.0**	**4.4 - 6.8**

a. Numbers are rounded to two significant figures.
b. Source: Tables 4-22, 4-25, 4-28, and 4-31 for the construction phase, operations period, monitoring period, and closure phase, respectively.
c. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
d. For a 50-year working lifetime.
e. Totals might differ from sums of values due to rounding.

The maximally exposed worker is a subsurface worker whose 50-year working lifetime would span the 50-year operations period needed for aging of spent nuclear fuel. This worker would be a locomotive operator or brakeman who is involved in the transport and emplacement of the spent nuclear fuel. Receiving an estimated radiation dose of about 30 rem, the probability of incurring a latent cancer fatality would be about 0.0012 for this individual.

The total estimated number of latent cancer fatalities that could occur in the repository workforce from the radiation dose received over the entire project would be about 4 for the 115 years of exposure during the higher-temperature operating mode. The number of latent cancer fatalities would range from 4.4 to 6.8, for the 171 to 341 years, respectively, of the lower-temperature operating mode. About 80 percent of the dose and associated risk of latent cancer fatality would occur during the operations period for surface and subsurface workforce. The principal source of exposure would be external radiation from spent nuclear fuel handling in surface facilities and waste package emplacement in the subsurface facility. Inhalation of radon-222 and its decay products by subsurface workers would account for 25 percent of the total worker dose. Ambient radiation exposure to subsurface workers would account for about 10 percent of the total worker dose.

4.1.7.5.3 *Total Radiological Health Impacts to the Public for All Phases*

The estimated radiation dose and radiological health impacts to the public for the entire project—which includes the period prior to final repository closure—are listed in Table 4-35. Dose and the potential radiological impact are listed for the offsite maximally exposed individual, assumed to reside continuously for a 70-year lifetime at the southern boundary of the land withdrawal area. This individual would have a probability of latent cancer fatality of 0.000031 or less from exposure to radionuclides released from the repository during the preclosure period. More than 99.9 percent of the potential health impact would be from naturally occurring radon-222 and its decay products released in exhaust

Table 4-35. Total dose and radiological impacts to the public for all phases.[a,b,c,d]

	Operating mode			
	Higher-temperature	Lower-temperature[e]	Higher-temperature	Lower-temperature[e]
Dose and health impact	Entire project		Maximum annual	
Maximally exposed individual[f]				
Dose (millirem)	31	44 - 62	0.73	1 - 1.3
Latent cancer fatality probability	1.6×10^{-5}	$2.2 - 3.1 \times 10^{-5}$	3.7×10^{-7}	$5.2 - 6.7 \times 10^{-7}$
Exposed 80-km population[g]				
Collective dose (person-rem)	930	1,900 - 3,900	14	20 - 26
Number of latent cancer fatality	0.46	0.97 - 2	0.0071	0.010 - 0.013

a. Numbers are rounded to two significant figures.
b. Source: Table 4-8, Section 4.1.2.5.
c. Greater than 99.9 percent of dose would be from naturally occurring radon-222 and decay products.
d. Project would last from 115 to 341 years.
e. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
f. Individual located at the southern boundary of the land withdrawal area for a 70-year lifetime including all of the operations period (24 or 50 years) with the remainder during the monitoring period.
g. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

ventilation air. The highest annual radiation dose would range from 0.73 to 1.3 millirem, less than 1 percent of the annual 200-millirem dose to members of the public in Amargosa Valley from ambient levels of naturally occurring radon-222 and its decay products (Chapter 3, Section 3.1.8.2).

The collective or population dose and associated radiological health impacts are listed in Table 4-35 for the population within 80 kilometers (50 miles) for the entire project duration, ranging from 115 years for the higher-temperature operating mode up to 341 years for the lower-temperature operating mode. An estimated 0.46 latent cancer fatality would occur for the higher-temperature operating mode, and from 0.97 to 2.0 latent cancer fatalities would occur for the lower-temperature operating mode. Statistics published by the Centers for Disease Control indicate that during 1998, 24 percent of all deaths in the State of Nevada were attributable to cancer of some type and cause (DIRS 153066-Murphy 2000, p. 8). Assuming this rate would remain unchanged for the estimated population (in 2035) of about 76,000 within 80 kilometers (50 miles) of the Yucca Mountain site, about 18,000 members of this population would be expected to die from cancer-related causes. During the time the project was active, the number of cancer deaths unrelated to the project would range from about 30,000 to 89,000 in the general population. Estimated project-related impacts (0.46 to 2 latent cancer fatalities) would be a very small increase (0.007 percent or less) over this baseline. The potential human health impacts of long-term repository performance are discussed in Chapter 5.

4.1.8 ACCIDENT SCENARIO IMPACTS

This section describes the impacts from potential accident scenarios from performance confirmation, construction, operation and monitoring, and closure activities. The analysis is separated into radiological accidents (Section 4.1.8.1) and nonradiological accidents (Section 4.1.8.2). The analysis of radiological accident consequences used the MACCS2 computer code (DIRS 103168-Chanin and Young 1998, all). The receptors would be (1) the *maximally exposed individual,* defined as a hypothetical member of the public at the point on the land withdrawal boundary that would receive the largest dose from the assumed accident scenario, (2) the *involved worker,* a worker who would be handling the spent nuclear fuel or high-level radioactive waste when the accident occurred, (3) the *noninvolved worker*, a worker near the accident but not involved in handling the material, and (4) members of the public who reside within

Main Index Vol 1 Index

approximately 80 kilometers (50 miles) of the proposed repository. All analysis method details are provided in Appendix H.

The impacts to offsite individuals from repository accidents would be small, with calculated doses of 0.038 rem or less to the maximally exposed offsite individual. Doses to a maximally exposed noninvolved worker would be higher than those to offsite individuals, up to 16 rem. Some of the very unlikely accidents would be expected to severely injure or kill involved workers.

4.1.8.1 Radiological Accidents

The first step in the radiological accident analysis was to examine the initiating events that could lead to facility accidents. These events could be external or internal. External initiators originate outside a facility and affect its ability to confine radioactive material. They include human-caused events such as aircraft crashes, external fires and explosions, and natural phenomena such as seismic disturbances and extreme weather conditions. Internal initiators occur inside a facility and include human errors, equipment failures, or combinations of the two. DOE analyzed initiating events applicable to repository operations to define subsequent sequences of events that could result in releases of radioactive material or radiation exposure. For each event in these accident sequences, the analysis estimated and combined probabilities to produce an estimate of the overall accident probability for the sequence. In addition, the analysis used bounding (plausible upper limit) accident scenarios to represent the impacts from groups of similar accidents. Finally, it evaluated the consequences of the postulated accident scenarios by estimating the potential radiation dose and radiological impacts.

ACCIDENT TYPES

Radiological accidents are unplanned events that could result in exposure of nearby humans to direct radiation or to radioactive material that would be ingested or inhaled.

Nonradiological accidents are unplanned events that could result in exposure of nearby humans to hazardous or toxic materials released to the environment as a result of the accident.

The analysis used accident analyses previously performed by others for repository operation whenever possible to identify potential accidents. DOE reviewed these analyses for their applicability to the repository before using them (see Appendix H). The spectrum of accident scenarios evaluated in the analysis is based on the current conceptual design of the facility. Final facility design details are not available; the final designs could affect both the frequency and consequences of postulated accidents. For areas without final facility design criteria, DOE made assumptions to ensure that the analysis did not underestimate impacts.

The radionuclide *source term* for various accident scenarios could involve several different types of radioactive materials. These would include commercial spent nuclear fuel from both boiling- and pressurized-water commercial reactors (see Appendix A, Section A.2.1), DOE spent nuclear fuel (see Appendix A, Section A.2.2), DOE high-level radioactive waste incorporated in a glass matrix (see Appendix A, Section A.2.3), and weapons-grade plutonium either immobilized in high-level radioactive waste glass matrix or as mixed-oxide fuel (see Appendix A, Section A.2.4). Appendix A contains information on the radionuclide inventories in these materials. The analysis also examined accident scenarios involving the release of low-level waste generated and handled at the repository, primarily in the Waste Treatment Building.

The analysis used the radionuclide inventories from Appendix A for a representative fuel element to estimate the material that could be involved in an accident. It used the MACCS2 computer program, developed under the guidance of the Nuclear Regulatory Commission, to estimate potential radiation doses to exposed individuals (onsite and offsite) and population groups from postulated accidental releases of radionuclides. Appendix H contains additional information on the MACCS2 program and the models and assumptions incorporated in it.

The analysis considered radiological consequences of the postulated accidents for the following individuals and populations:

- *Involved worker.* A facility worker directly involved in activities at the location where the postulated accident could occur
- *Maximally exposed noninvolved worker (collocated worker).* A worker not directly involved with material unloading, transfer, and emplacement activities, assumed to be 100 meters (330 feet) downwind of the facility where the release occurs
- *Maximally exposed offsite individual.* A hypothetical member of the public at the nearest point to the facility at the site boundary. The analysis determined that the land withdrawal boundary location with the highest potential exposure from an accidental release of radioactive material would be either about 8 or 11 kilometers (5 or 7 miles) from the accident location (at the western boundary of the land withdrawal area analyzed). The maximally exposed individual for a single-point release of material is different than those for a continuous release (see Section 4.1.2) because the maximally exposed individual could not be present continuously at the western boundary because this is government-owned land.
- *Offsite population.* Members of the public within 80 kilometers (50 miles) of the repository site (see Chapter 3)

Ten accident scenarios were analyzed in detail. These scenarios bound the consequences of credible accidents at the repository. They include accidents in the Cask/Handling Area, the Canister Transfer System, the Assembly Transfer System, the Disposal Container Handling Area, and the Waste Treatment Building. The scenarios consider drops and collisions involving shipping casks, bare fuel assemblies, low-level radioactive waste drums, and the waste package transporter.

The 10 accident scenarios in Tables 4-36 and 4-37 replace the 16 accident scenarios analyzed in the Draft EIS. The number of scenarios was reduced because several accidents analyzed in the Draft EIS were found to be no longer credible based on design changes, revised system-failure probabilities, and new information on the capability of DOE canisters and transportation casks to withstand drops. Details of these changes are in Appendix H, Section H.2.1.1.

Table 4-36 lists the results of the radiological accident consequence analysis under median, or 50th-percentile meteorological conditions. Table 4-37 lists similar information based on unfavorable meteorological conditions (95th-percentile, or those conditions that would not be exceeded more than 5 percent of the time) that tend to maximize potential radiological impacts. Impacts to the noninvolved worker would result from the inhalation of airborne radionuclides and external radiation from the passing plume. Impacts to the maximally exposed offsite individual and the offsite population would result from these exposure pathways and from long-term external exposure to radionuclides deposited on soil during plume passage, subsequent ingestion of radionuclides in locally grown food, and inhalation of resuspended particulates. The analysis did not consider interdiction by DOE or other government agencies to limit long-term radiation doses because none of these doses would be above the Environmental Protection Agency's Protective Action Guides. Interdiction would be likely to occur if the calculated accident doses exceeded these guides.

Table 4-36. Radiological consequences of repository operations accident scenarios for median (50th-percentile) meteorological conditions.

		Maximally exposed offsite individual[c]		Population		Noninvolved worker		Involved worker	
Accident scenario[a,b]	Frequency (per year)[a]	Dose (rem)	LCFi[d]	Dose (person-rem)	LCFp[d]	Dose (rem)	LCFi	Dose (rem)	LCFi
1. Basket drop onto another basket in pool (PWR fuel)	0.04	8.2×10^{-7}	4.1×10^{-10}	4.9×10^{-4}	2.4×10^{-7}	3.6×10^{-4}	1.4×10^{-7}	(e)	(e)
2. Basket drop onto another basket in dryer (PWR fuel)	0.04	8.7×10^{-6}	4.4×10^{-9}	8.9×10^{-4}	4.4×10^{-7}	4.5×10^{-3}	1.8×10^{-6}	(e)	(e)
3. Drop of transfer basket onto another basket in dryer (BWR fuel)	$7.4 \text{ x } 10^{-3}$	6.4×10^{-6}	3.2×10^{-9}	6.0×10^{-4}	3.0×10^{-7}	3.1×10^{-5}	1.2×10^{-8}	(e)	(e)
4. Unsealed DC drop and slapdown in cell (PWR fuel)	8.4×10^{-3}	2.6×10^{-5}	1.3×10^{-8}	2.5×10^{-3}	1.2×10^{-6}	1.3×10^{-2}	5.2×10^{-6}	(e)	(e)
5. Unsealed shipping cask drop in CPP (PWR fuel)	8.7×10^{-3}	3.4×10^{-5}	1.8×10^{-8}	3.0×10^{-3}	1.5×10^{-6}	1.8×10^{-2}	7.4×10^{-6}	(e)	(e)
6. Unsealed shipping cask drop in pool (PWR fuel)	8.7×10^{-3}	2.5×10^{-6}	1.3×10^{-9}	1.5×10^{-3}	7.3×10^{-7}	1.0×10^{-3}	4.1×10^{-7}	(e)	(e)
7. Transporter runaway and derailment (PWR fuel)	1.2×10^{-7}	1.0×10^{-2}	5.0×10^{-6}	0.14	7.3×10^{-5}	3.2	1.3×10^{-3}	(f)	(f)
8. Beyond design basis earthquake in WHB (PWR fuel)	2.0×10^{-5}	1.2×10^{-2}	6.0×10^{-6}	0.63	3.2×10^{-4}	4.9	2.0×10^{-3}	(f)	(f)
9. Earthquake with fire in WTB	2.0×10^{-5}	1.6×10^{-5}	8.0×10^{-9}	8.9×10^{-4}	4.4×10^{-7}	8.2×10^{-4}	3.3×10^{-7}	(f)	(f)
10. Low level waste drum rupture in WTB	0.59	5.7×10^{-10}	2.9×10^{-13}	3.0×10^{-8}	1.4×10^{-11}	2.5×10^{-8}	1.0×10^{-11}	8.8×10^{-5}	3.5×10^{-8}

a. Source: Appendix H
b. DC = Disposal Container, CPP = Cask Preparation Pit, PWR = Pressurized Water Reactor, BWR = Boiling Water Reactor, WHB = Waste Handling Building, WTB = Waste Treatment Building.
c. Assumed to be at the nearest land withdrawal boundary, which would be 11 kilometers (7 miles) for all accident scenarios except 7. For these accidents, the distance would be 8 kilometers (5 miles).
d. LCFi is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the estimated number of cancers in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as discussed in Appendix F, Section F.1.1.5.
e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident because operations are done remotely. Thus, involved worker impacts were not evaluated.
f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on staffing projections (DIRS 104718-CRWMS M&O 1998, pp. 17 and 18).

The *maximum reasonably foreseeable accident scenario* (earthquake, Table 4-37, number 8) for the 95-percent weather conditions would result in an estimated 0.011 additional latent cancer fatality for the same affected population. The more conservative summation of all foreseeable accidents in Table 4-37 results in less than 0.02 additional latent cancer fatality for the exposed population. Thus, the estimated number of latent cancer fatalities for the offsite individuals from accidents would be very small.

The results described in this section assumed that all commercial spent nuclear fuel would arrive at the repository either uncanistered or in canisters not suitable for disposal. In this base case scenario, all of the fuel would have to be handled as bare fuel assemblies in the Waste Handling Building and placed in disposal containers for disposal, as described above. The base case scenario, which assumes that all fuel would have to be handled as bare fuel assemblies, provides a bounding assessment of accident impacts compared to canistered scenarios. The uncanistered fuel, as indicated in Tables 4-36 and 4-37, represents the more meaningful accident risk because of the additional handling operations required and the higher impacts associated with accidents involving bare assemblies. As a consequence, the base case evaluated in this section provides a bounding assessment of accident impacts in relation to the packaging scenarios.

Table 4-37. Radiological consequences of repository operations accident scenarios for unfavorable (95th-percentile) meteorological conditions.

Accident scenario[a,b]	Frequency (per year)[b]	Maximally exposed offsite individual[c] Dose (rem)	LCFi[d]	Population Dose (person-rem)	LCFp[d]	Noninvolved worker Dose (rem)	LCFi	Involved worker Dose (rem)	LCFi
1. Basket drop onto another basket in pool (PWR fuel)	0.04	3.3×10^{-6}	1.7×10^{-9}	4.0×10^{-2}	2.0×10^{-5}	2.0×10^{-3}	8.0×10^{-7}	(e)	(e)
2. Basket drop onto another basket in dryer (PWR fuel)	0.04	3.2×10^{-5}	1.6×10^{-8}	4.7×10^{-2}	2.3×10^{-5}	2.3×10^{-2}	9.2×10^{-6}	(e)	(e)
3. Drop of transfer basket onto another basket in dryer (BWR fuel)	7.4×10^{-3}	2.3×10^{-5}	1.2×10^{-8}	3.0×10^{-2}	1.4×10^{-5}	1.6×10^{-4}	6.4×10^{-8}	(e)	(e)
4. Unsealed DC drop and slapdown in cell (PWR fuel)	8.4×10^{-3}	9.3×10^{-5}	4.7×10^{-8}	0.12	6.2×10^{-5}	7.4×10^{-2}	3.0×10^{-5}	(e)	(e)
5. Unsealed shipping cask drop in CPP (PWR fuel)	8.7×10^{-3}	1.1×10^{-4}	5.5×10^{-8}	0.14	7.2×10^{-5}	0.10	4.1×10^{-5}	(e)	(e)
6. Unsealed shipping cask drop in pool (PWR fuel)	8.7×10^{-3}	1.0×10^{-5}	5.0×10^{-9}	0.12	6.0×10^{-5}	6.0×10^{-3}	2.4×10^{-6}	(e)	(e)
7. Transporter runaway and derailment (PWR fuel)	1.2×10^{-7}	3.8×10^{-2}	1.9×10^{-5}	4.3	2.2×10^{-3}	16	6.4×10^{-3}	(e)	(e)
8. Beyond design basis earthquake in WHB (PWR fuel)	2.0×10^{-5}	3.8×10^{-2}	1.9×10^{-5}	21	1.1×10^{-2}	25	9.8×10^{-3}	(f)	(f)
9. Earthquake with fire in WTB	2.0×10^{-5}	5.4×10^{-5}	2.7×10^{-8}	3.1×10^{-2}	1.5×10^{-5}	6.5×10^{-3}	2.6×10^{-6}	(f)	(f)
10. Low level waste drum rupture in WTB	0.59	1.6×10^{-9}	8.0×10^{-13}	1.1×10^{-6}	5.3×10^{-10}	2.0×10^{-7}	8.0×10^{-11}	8.8×10^{-5}	3.5×10^{-8}

a. Source: Appendix H.

b. DC = Disposal Container, CPP = Cask Preparation Pit, PWR = Pressurized Water Reactor, BWR = Boiling Water Reactor, WHB = Waste Handling Building, WTB = Waste Treatment Building.

c. Assumed to be at the nearest land withdrawal boundary, which would be 11 kilometers (7 miles) for all accidents except 7. For these accidents, the distance would be 8 kilometers (5 miles).

d. LCFi is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the estimated number of cancers in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as discussed in Section F.1.1.5.

e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident because operations are done remotely. Thus, involved worker impacts were not evaluated.

f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on staffing projections (DIRS 104718-CRWMS M&O 1998, pp. 17 and 18).

The analysis also evaluated the probability of an aircraft crash onto storage modules which could be used in a surface aging facility. A military aircraft crash onto a storage module was found to be a reasonably foreseeable event; however, the analysis determined that the aircraft would not penetrate the storage module and no release would occur. A crash of a commercial jet airliner into the surface aging facility was also evaluated, even though the probability of such an event is not reasonably foreseeable. The results of the evaluation also indicate no penetration of the storage modules and no release of radiological materials. Details are provided in Appendix H, Section H.2.1.3.

In addition to the reasonably foreseeable accidents summarized in this section, DOE evaluated a hypothetical beyond-credible event (annual probability less than 1 in 10 million) involving an aircraft crash into the repository (see Appendix H, Section H.2.1.5.1). It was determined that an aircraft crash into the Waste Handling Building would result in the maximum estimated consequences. DOE assumed that evacuation of potentially exposed individuals would occur one day after the event, and also that contaminated food and water would be monitored and confiscated if necessary. The dose to the maximally exposed individual was estimated to be 4.5 rem, with a 0.0023 probability of a latent cancer fatality. The dose to the population within 80 kilometers (50 miles) was estimated to be 78 person-rem, with 0.039 latent cancer fatality resulting from this dose.

4.1.8.2 Nonradiological Accidents

A potential release of hazardous or toxic materials during postulated operational accidents involving spent nuclear fuel or high-level radioactive waste at the repository would be very unlikely. Because of the large quantities of radioactive material, radiological considerations would outweigh nonradiological concerns. The repository would not accept hazardous waste as defined by the Resource Conservation and Recovery Act. Some potentially hazardous metals such as arsenic or mercury could be present in the high-level radioactive waste. However, they would be in a vitrified glass matrix that would make the exposure of workers or members of the public from operational accidents highly unlikely. Appendix A contains more information on the inventory of potentially hazardous materials.

Some potentially nonradioactive hazardous or toxic substances would be present in limited quantities at the repository as part of operational requirements. Such substances would include liquid chemicals such as cleaning solvents, sodium hydroxide, sulfuric acid, and various solid chemicals (see Section 4.1.3.2). These substances are in common use at other DOE sites. Section 4.1.7 describes potential impacts to workers from normal industrial hazards in the workplace (which includes industrial accidents). The statistics used in the analysis were derived from DOE accident experience at other sites. Impacts to members of the public would be unlikely because the chemicals would be mostly liquid and solid so that any release would be confined locally. (For example, chlorine at the site used for water treatment would be in powder form, so a gaseous release of chlorine would not be possible. Propane gas would not be stored at the site.)

Section 4.1.12.2 describes the quantities of solid hazardous waste generated during repository operations. The construction and closure phases would not generate liquid hazardous waste. The generation, storage, and shipment off the site of solid and liquid hazardous waste generated during operations would represent minimal incremental risk from accidents. Impacts to workers from industrial accidents in the workplace are part of the statistics presented in Appendix F, Section F.2.

4.1.8.3 Sabotage

In the aftermath of the tragic events of September 11, DOE is continuing to assess measures that it could take to minimize the risk or potential consequences of radiological sabotage or terrorist attacks against our Nation's proposed monitored geologic repository.

Over the long term (after closure), deep geologic disposal of spent nuclear fuel and high-level radioactive waste would provide optimal security by emplacing the material in a geologic formation that would provide protection from inadvertent and advertent human intrusion, including potential terrorist activities. The use of robust metal waste packages to contain the spent nuclear fuel and high-level radioactive waste more than 200 meters (660 feet) below the surface would offer significant impediments to any attempt to retrieve or otherwise disturb the emplaced materials.

In the short term (prior to closure), the proposed repository at Yucca Mountain would offer certain unique features from a safeguards perspective: a remote location, restricted access afforded by Federal land ownership and proximity to the Nevada Test Site, restricted airspace above the site, and access to a highly effective rapid-response security force.

Current Nuclear Regulatory Commission regulations (10 CFR 63.21 and 10 CFR 73.51) specify a repository performance objective that provides "high assurance that activities involving spent nuclear fuel and high-level waste do not constitute an unreasonable risk to public health and safety." The regulations require that spent nuclear fuel and high-level radioactive waste be stored in a protected area such that:

- Access to the material requires passage through or penetration of two physical barriers. The outer barrier must have isolation zones on each side to facilitate observation and threat assessment, be continually monitored, and be protected by an active alarm system.
- Adequate illumination must be provided for observation and threat assessment.
- The area must be monitored by random patrol.
- Access must be controlled by a lock system, and personnel identification must be used to limit access to authorized persons.

A trained, equipped, and qualified security force is required to conduct surveillance, assessment, access control, and communications to ensure adequate response to any security threat. Liaison with a response force is required to permit timely response to unauthorized entry or activities. In addition, the Nuclear Regulatory Commission requires (10 CFR Part 63, by reference to 10 CFR Part 72) that comprehensive receipt, periodic inventory, and disposal records be kept for spent nuclear fuel and high-level radioactive waste in storage. A duplicate set of these records must be kept at a separate location.

DOE believes that the safeguards applied to the proposed repository should involve a dynamic process of enhancement to meet threats, which could change over time. Repository planning activities would continue to identify safeguards and security measures that would further protect fixed facilities from terrorist attack and other forms of sabotage. Additional measures that DOE could adopt include:

- Facilities with thicker reinforced walls and roofs designed to mitigate the potential consequences of the impact of airborne objects
- Underground or surface bermed structures to lessen the severity of damage in cases of aircraft crashes
- Additional doors, airlocks, and other features to delay unauthorized intrusion
- Additional site perimeter barriers to provide enhanced physical protection of site facilities
- Active denial systems to disable any adversaries, thereby preventing access to the facility

Although it is not possible to predict if sabotage events would occur, and the nature of such events if they did occur, DOE examined various accident scenarios that approximate the types of consequences that could occur. These accidents and their consequences are discussed in Section 4.1.8.1.

4.1.9 NOISE IMPACTS

This section describes possible noise impacts to the public (nuisance noise) and workers (occupational noise) from performance confirmation, construction, operation and monitoring, and closure activities. Repository areas that could generate elevated noise levels include the North Portal, South Portal, Emplacement Shaft, and Development Shaft Operations Areas. The following discussion identifies potential impacts that primarily would affect workers during routine operations. Overall, however, the potential for noise impacts to the public would be very small due to the distances of residences from these areas. Section 4.1.4.2 discusses noise impacts on wildlife.

4.1.9.1 Noise Impacts from Performance Confirmation

As part of site characterization, DOE has evaluated existing noise conditions in the Yucca Mountain region. The noise associated with site characterization activities, which has included that from construction, equipment, drilling equipment, and occasional blasting, has not resulted in noticeable impacts. Because performance confirmation activities would be similar to those for site characterization, no impacts would be expected.

4.1.9.2 Noise Impacts from Construction, Operation and Monitoring, and Closure

Sources of noise in the analyzed land withdrawal area during the construction phase would include activities at the North Portal and Ventilation Shaft Operations Areas and South Portal Development Area involving heavy equipment (bulldozers, graders, loaders, pavers, etc.), cranes, ventilation fans, and diesel generators. Sources of noise during the operation and monitoring phase would include transformer noise, compressors, ventilation fans, air conditioners, and a concrete batch plant. Ventilation fans would have silencers that would keep noise levels below 85 dBA (see Chapter 3, Section 3.1.9 for an explanation of noise measurements) at a distance of 3 meters (10 feet) (DIRS 100235-CRWMS M&O 1997, p. 107). The Occupational Safety and Health Administration has identified that the maximum permissible continuous noise level that workers may be exposed to without controls is 90 dBA [29 CFR 1910.95(b)(2)].

The distance from the North Portal Operations Area to the nearest point on the boundary of the analyzed land withdrawal area analyzed would be about 11 kilometers (7 miles) due west. The distance from the South Portal Development Area to the nearest point on the land withdrawal area boundary would also be about 11 kilometers due west. The point on the boundary closest to a Ventilation Shaft Operations Area would be about 7 kilometers (4 miles) (DIRS 104852-YMP 1997, all).

To establish the propagation distance of repository-generated noise for analysis purposes, DOE used an estimated maximum sound level [132 decibels, A-weighted (dBA) for heavy construction equipment, although heavy trucks generate sound levels of between 70 and 80 dBA at 15 meters (50 feet)]. An analysis determined the distance at which that noise would be at the lower limit of human hearing (20 dBA). The calculated distance was 6 kilometers (3.7 miles). Thus, noise impacts would be unlikely at the land withdrawal area boundary.

Because the distance between repository noise sources and a hypothetical individual at the land area withdrawal boundary would be large enough to reduce the noise to background levels and because there would be no residential or community receptors at the withdrawal area boundary [the nearest housing is in Amargosa Valley about 22 kilometers (14 miles) from the repository site], DOE expects no noise impacts to the public from repository construction and operations.

Workers at the repository site could be exposed to elevated levels of noise. Small impacts such as speech interference between workers and annoyance to workers would occur. However, worker exposures during all *repository phases* would be controlled such that impacts (such as loss of hearing) would be unlikely. Engineering controls would be the primary method of noise control. Hearing protection would be required, as needed, as a supplement to engineering controls.

Noise impacts associated with closure would be similar to those associated with construction and operations. Therefore, DOE expects no noise impacts to the public and workers.

4.1.10 AESTHETIC IMPACTS

This section describes potential aesthetic impacts from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. These activities would not cause adverse impacts to aesthetic or visual resources in the region. The analysis of such impacts considered the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. The analysis gave specific consideration to scenic quality, visual sensitivity, and distance from observation points.

Yucca Mountain has visual characteristics fairly common to the region (a scenic quality rating of C), and visibility of the repository site from publicly accessible locations is low or nonexistent. The intervening Striped Hills and the low elevation of the southern end of Yucca Mountain and Busted Butte would obscure the view of repository facilities from the south near the Town of Amargosa Valley, approximately 22 kilometers (14 miles) away. There is no public access to the north or east of the site to enable viewing of the facilities. The only structures that could potentially be visible from the west and exceed the elevation of the southern ridge of Yucca Mountain [1,500 meters (4,900 feet)] would be the ventilation exhaust stacks (numbering 3 to 9) and support structures that could be located along the crest of the mountain. The exhaust stacks could be approximately 15 to 18 meters (50 to 60 feet) high, but a lower profile design could be implemented. The ventilation system would include intake and exhaust stacks, support structures, and access roads. The ventilation system would be constructed and maintained on approximately 105 acres and would include approximately 30 structures (DIRS 153849-DOE 2001, p. 2-33). Some of the exhaust stacks would likely be located along the crest of the mountain, while the intakes would be constructed along the eastern side of the ridge. The height of the ventilation intake structures would be lower than the exhaust stacks and would be constructed at lower elevations. Therefore, the intake stacks would not be as likely to impact the area aesthetically as the exhaust stacks. The presence of exhaust ventilation stacks on the crest of Yucca Mountain could be an aesthetic aggravation to Native Americans.

The intake and exhaust ventilation stacks might be angled, thereby lowering the height of the structure and lessening impact. Recontouring the area in the vicinity of the ventilation system structures and the use of natural vegetation as screening would also lessen potential impact. Because of the height of the ventilation stack structures above Yucca Mountain, the Federal Aviation Administration or the Air Force might require flashing beacon lights atop the stacks. If beacons were required, they could be visible for a great distance, especially west of Yucca Mountain. Closure activities, such as dismantling facilities and reclaiming the site, would improve the visual quality of the landscape. Adverse impacts to the visual quality due to closure would be unlikely.

DOE would provide lighting for operation areas at the repository. This lighting could be visible from public access points, especially from the west due to the ventilation structures atop Yucca Mountain. There would not be significant visual impacts due to repository lighting to users of Death Valley National Park. The towns of Amargosa Valley, Beatty, and Pahrump, located between the park and the repository, probably would cause greater impact to the nightly *viewshed* than operational lighting of the repository. The visual impact of the lighting from Las Vegas would also have significantly more impact in the region than that of the proposed repository. The use of shielded or directional lighting at the repository would limit the amount of light that could be viewed from outside the repository operational area.

As described in Section 4.1.1.2, land disturbance for the operating modes would not differ greatly, ranging from 4.3 to 6.0 square kilometers (1,000 to 1,500 acres), a small fraction of the 600 square kilometers withdrawn for the repository. The aesthetic impacts of the land disturbance resulting from implementation of the Proposed Action design would be temporary.

4.1.11 IMPACTS TO UTILITIES, ENERGY, MATERIALS, AND SITE SERVICES

This section discusses potential impacts to residential water, energy, materials, and site services from performance confirmation, construction, operation and monitoring, and closure activities. The scope of the analysis included electric power use, fossil-fuel and oil and lubricant consumption, consumption of construction materials, and onsite services such as emergency medical support, fire protection, and security and law enforcement. The analysis compared needs to available capacity. The region of influence would include the local, regional, and national supply infrastructure that would have to satisfy the needs. The analysis used engineering estimates of requirements for construction materials, utilities, and energy.

Construction activities would occur during both the construction and the operation and monitoring phases. Table 4-38 lists electric energy, fossil-fuel, and oil and lubricant use during the different phases. Table 4-39 lists construction material use. Both tables list comparative values for the higher-temperature operating mode and a range of values for the lower-temperature operating mode. DOE prorated impacts to site services, if any, with those to the commodity areas to produce an estimate of overall impacts.

Overall, DOE expects only small impacts to residential water, energy, materials, and site services from the Proposed Action. DOE would, however, have to enhance the electric power delivery system to the Yucca Mountain site for the operating modes considered.

4.1.11.1 Impacts to Utilities, Energy, Materials, and Site Services from Preconstruction Testing and Performance Confirmation

DOE would obtain utilities, energy, and materials for preconstruction testing and performance confirmation activities from existing sources and suppliers. Water would come from existing wells. Power would come from regional suppliers to the existing Nevada Test Site transmission system. Based on site characterization activities, these activities would not cause meaningful impacts to regional utility, energy, and material sources. In addition, DOE would continue to use such existing site services as emergency medical support, fire protection, and security and law enforcement (as described in Chapter 3, Section 3.1.11.3) during preconstruction testing and performance confirmation.

4.1.11.2 Impacts to Utilities, Energy, Materials, and Site Services from Construction, Operation and Monitoring, and Closure

Residential Water

Population growth associated with the Proposed Action could affect regional water resources. Based on the information in Section 4.1.6, in 2030 the Proposed Action would result in a maximum population increase of about 6,200 in Clark and Nye Counties. About 80 percent of these people would live in Clark County and about 20 percent in Nye County. Whether domestic water needs were satisfied predominantly from surface-water sources, as is the case for most of Clark County, or from groundwater sources, as for most of Nye County, these relatively small increases in population would have very minor impacts on existing water demands.

The maximum project-related population increase for Clark County would amount to about 0.4 percent of the 2000 population and less than 0.2 percent of the County's population in 2030 (see Chapter 3, Section 3.1.7). Correspondingly, the associated increase in water demand in the county as a result of the proposed project would be very small. The population of Indian Springs in Clark County would increase by a projected maximum of about 180 as a result of the Proposed Action. This number represents about 14 percent of the 2000 Indian Springs population and, based on a Las Vegas Valley average demand for domestic water of 720 liters (190 gallons) per day per person (DIRS 148196-SNWA 1999, all), would require a quantity of water that is about 9 percent of the community's quasimunicipal groundwater

Table 4-38. Electricity and fossil-fuel use for the Proposed Action.[a]

Phase	Operating mode	
	Higher-temperature	Lower-temperature
Phase/activity durations (years)		
Construction phase	5	5
Operations and monitoring phase		
Operations	24	24 or 50
Monitoring	76	99 - 300
Closure phase	10	11 - 17
Total	***115***	***171 - 341***[a]
Peak electric power (megawatts)		
Construction phase	25	25
Operations and monitoring phase		
Operations	47	40 - 54
Monitoring	7.7	7.8 - 15
Closure phase	10	10 - 18
Maximum	*47*	*40 - 54*
Electricity use (1,000 megawatt-hours)		
Construction phase	150	190 - 210
Operations and monitoring phase		
Operations	5,200	5,300 - 9,200
Monitoring	4,800	9,700 - 29,000
Closure phase	720	790 - 1,300
Total	***11,000***	***16,000 - 36,000***[a]
Fossil fuel (million liters)		
Construction phase	5.5	5.5 - 6
Operations and monitoring phase		
Operations	360	370 - 500
Monitoring	2.3	2.6 - 13
Closure phase	5.2	5.1 - 6.6
Total	***370***	***380 - 510***[a]
Oils and lubricants (million liters)		
Construction phase	2.6	3.1 - 3.5
Operations and monitoring phase		
Operations	8.5	9.8 - 18
Monitoring	9	13 - 53
Closure phase	2	1.8 - 3
Total	***22***	***33 - 71***[a]

a. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

withdrawal in 1997 [0.51 million cubic meters (410 acre-feet)] (DIRS 102170-NDCNR 1998, all). DOE expects the population of Indian Springs to be larger by 2030 and on a percentage basis, the contribution (and associated water demand) from project-related growth would be smaller than current numbers. However, this small community would be more likely to be affected by projected growth than other areas in Clark County.

In Nye County, estimates of domestic water demand for 1995 are about 750 liters (200 gallons) per day per person (DIRS 104888-Le Strange 1997, Table 10). At this demand, the project-related increase in Nye County population would result in an additional water demand of about 0.30 million cubic meters (240 acre-feet) of water per year. This represents about 0.3 percent of the water use in Nye County in 1995. As indicated in Section 4.1.6, most (about 92 percent) of the project-related growth in Nye County would occur in Pahrump. This would equate to adding about 0.28 million cubic meters (220 acre-feet) to Pahrump's annual water demand, which represents about 0.9 percent of the 1995 Pahrump water

Table 4-39. Construction material use for the Proposed Action.[a]

Usage	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Phase/activity durations (years)		
Construction phase	5	5
Operations and monitoring phase		
Operations	24	24 or 50
Monitoring	76	99 - 300
Closure phase	10	11 - 17
Total	***115***	***171 - 341***[a]
Concrete (1,000 cubic meters)		
Construction phase	420	490 - 500
Operations and monitoring phase		
Operations	240	350 - 880
Monitoring	0	0
Closure phase	3	3 - 5
Total	***670***	***850 - 1,400***[a]
Cement (1,000 metric tons)		
Construction phase	160	190
Operations and monitoring phase		
Operations	100	150 - 340
Monitoring	0	0
Closure phase	1.2	1.2 - 1.9
Total	***250***	***310 - 530***[a]
Steel (1,000 metric tons)		
Construction phase	100	120
Operations and monitoring phase		
Operations	62	150 - 180
Monitoring	0	0
Closure phase	0.03	0.04
Total	***160***	***270 - 300***[a]
Copper (1,000 metric tons)		
Construction phase	0.2	0.23
Operations and monitoring phase		
Operations	0.08	0.24 - 0.6
Monitoring	0	0
Closure phase	0	0
Total	***0.3***	***0.5 - 0.86***[a]

a. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

withdrawal of 30 million cubic meters (24,000 acre-feet). By 2030, when the peak population increases would occur, the project-related increase in water demand would be an even smaller percentage of the total Nye County and Pahrump water need. The increase in domestic water demand in Nye County as a result of the proposed project would be very small.

Residential Sewer

Sewer utilities could be affected by population growth associated with the Proposed Action. In Clark County, where most of the population growth would take place, the fact that the maximum project-related population increase would amount to about 0.4 percent of the 2000 population indicates that impacts to the populous areas of the county (that is, the Las Vegas Valley) would be very small. In Indian Springs, where project-related growth would be a more substantial portion of the community population, small treatment facilities designed for a specific area or individual household septic tank systems would accommodate wastewater treatment needs. In either case, the added population would not be likely to cause overloading to a sewer utility.

Growth in Nye Country from the Proposed Action would be likely to occur primarily in the Pahrump area. There is no reason to believe that project-related population increases would overload a sewer utility. Again, small, limited-service treatment facilities or individual septic tank and drainage field systems would provide the primary wastewater treatment capacities.

Electric Power

During the construction phase, the demand for electricity would increase as DOE operated two or three tunnel boring machines and other electrically powered equipment. The tunnel boring machines would account for more than half of the demand for electricity during the construction phase. The estimated peak demand for electric power during the construction phase would be about 25 megawatts with use varying between about 150,000 and 210,000 megawatt-hours, depending on the operating mode. Excavation activities for the operating modes would use two or three tunnel boring machines. However, the operations time would increase for the lower-temperature operating mode because of the increased tunnel lengths.

As discussed in Chapter 3, Section 3.1.11.2, the current electric power supply line has a peak capacity of only 10 megawatts. DOE, therefore, is evaluating modifications and upgrades to the site electrical system, as discussed below, under Repository Electric Power Supply Options.

During the operations period, the development of emplacement drifts would continue in parallel with emplacement activities. During this period, the peak electric power demand would be between 40 and 54 megawatts, depending on the operating mode.

Following the completion of excavation activities, the demand for electric power would drop to about 21 to 34 megawatts and would continue to decrease, following the completion of emplacement and decontamination activities, to less than 15 megawatts for monitoring and maintenance activities. The closure phase would last from 10 to 17 years, depending on the operating mode. The peak electric power demand would be less than 18 megawatts for either of the operating modes during closure.

The repository demand for electricity would be well within the expected regional capacity for power generation. Nevada Power Company, for example, experienced a growth in peak demand of nearly 30 percent from 1993 to 1997 and has demonstrated the ability to meet customer demand in this high-growth environment through effective planning (DIRS 103284-Vogel 1998, all). Nevada Power's current planning indicates that it intends to maintain a reserve capacity of 12 percent. In 2010, at the beginning of the operation and monitoring phase, Nevada Power projects a net peak load of 5,950 megawatts and is planning a reserve of 714 megawatts (DIRS 103413-NPC 1997, Figures 2 and 4). The maximum 54-megawatt demand that the repository would require would be less than 1 percent of the projected peak demand in 2010, and less than 8 percent of the planned reserve. While the accuracy and viability of long-term planning for electrical power demand is now more uncertain than in previous years, DOE expects that regional capacity planning would accommodate the future repository demand.

Repository Electric Power Supply Options

As discussed above, the estimated repository electric power demand would exceed the current electric distribution capacity to the site after construction began in 2005. DOE would have to increase the electric power capacity to the site to accommodate the initial demand of about 25 megawatts during the construction phase and to support the estimated peak demand of as much as 54 megawatts during the operations period. A range of options including a modification or upgrade of the existing transmission and distribution system is under consideration to meet the repository electricity demand (DIRS 102045-CRWMS M&O 1998, all). DOE eliminated consideration of onsite generation of electricity in conjunction with the onsite plant that would generate steam for heating because the steam plant would be much smaller than a plant needed for power generation. DOE would, however, construct and operate a solar power generating facility close to the North Portal to support repository operations. The solar facility, which could produce as much as 3 megawatts of power, would be a dual-purpose facility, serving as a demonstration of photovoltaic power generation and augmenting the overall repository electric power supply (as much as 7 percent). In addition, DOE would also investigate using power supplied from a 436-megawatt wind farm proposed for the Nevada Test Site. This private-sector enterprise is currently being evaluated and has been described in a recent draft environmental assessment (DIRS 154545-DOE 2001, all). DOE has issued a Notice of Intent to prepare an environmental impact statement for this project (66 *FR* 38650; July 25, 2001). Other onsite generation capacity would use diesel-powered generators for emergency equipment.

As discussed in Chapter 3, Section 3.1.11.2, the repository site receives electricity through a feeder line from the Canyon Substation, which is rated at 69 kilovolts and has a capacity of 10 megawatts. The minimum modification would be to upgrade this line to 40 to 54 megawatts, modify the Nevada Test Site power loop to support repository operations in conjunction with other Test Site activities, and upgrade utility feeder lines to the Nevada Test Site. The existing Nevada Test Site power loop has a rated capacity of about 72 megawatts, but preliminary analysis of loop performance with a typical repository load (about 40 megawatts) indicated that unacceptable voltage reductions could occur at some Test Site locations. The minimum modification to the power loop to reduce the potential for unacceptable voltage reductions would be to install capacitors in the loop. Other options to obtain satisfactory performance for the power loop would include upgrading sections of the loop and the utility-owned feeder lines to the loop. Additional options, which would be variations of this approach, would include providing upgraded power lines directly from the utilities to the repository site.

As discussed in Chapter 3, Section 3.1.11.2, two commercial utility companies supply electricity to the Nevada Test Site feeder lines that power the Test Site power loop. Nevada Power Company owns and operates a 138-kilovolt line from the Las Vegas area to the Mercury Switching Station on the Test Site. Valley Electric Association owns and operates 138- and 230-kilovolt lines from the Las Vegas area to Pahrump and a 138-kilovolt line from Pahrump to the Jackass Flats substation on the Test Site near Amargosa Valley. The options DOE is evaluating include upgrading either or both of these lines. The options also include connecting both utility feeder lines directly to the repository with new 138- or 230-kilovolt lines to either the North or South Portal to obtain independent redundant power capability. DOE has considered constructing a new power line from the Tonopah/Anaconda area to near the Town of Amargosa Valley through Beatty with a direct tie to the South Portal at the repository. All system modifications would include appropriate modifications to transformers and switchgear. The approach in all cases would be to use existing power corridors where possible to limit environmental impacts and to reduce the need for additional rights-of-way. Depending on the option chosen, National Environmental Policy Act analysis would be conducted, as appropriate.

Fossil Fuels

Fossil fuels used during the construction phase would include diesel fuel and fuel oil. Diesel fuel would be used primarily to operate surface construction equipment and equipment to maintain the excavated rock pile. Fuel oil would fire a steam plant at the North Portal, which would provide building and process heat for the North Portal Operations Area. During construction the estimated use of diesel fuel and fuel oil would be 5.5 million to 6.0 million liters (1.5 million to 1.6 million gallons). The regional supply capacity of gasoline and diesel fuel is about 3.8 billion liters (1 billion gallons) per year for the State of Nevada, based on motor fuel use (DIRS 148094-BTS 1997, all). About half of the State total is consumed in the three-county region of influence (Clark, Lincoln, and Nye Counties) with the highest consumption in Clark County, so yearly repository use during the construction phase would be less than 1 percent of the current regional consumption.

Fossil-fuel use during the operation and monitoring phase would be for onsite vehicles and for heating. It would range between about 370 million and 500 million liters (about 98 million and 130 million gallons) depending on the repository operating mode. The annual use would be highest during the operations period and would decrease substantially during the monitoring period. The projected use of liquid fossil fuels would be within the regional supply capacity and would cause little impact. As discussed above, motor fuel use in the State of Nevada in 1996 was about 3.8 billion liters (1 billion gallons) (DIRS 148094-BTS 1997, all), which provides the baseline for the regional supply capacity. The highest annual use during the operations period would be less than 0.5 percent of the 1996 capacity in Clark, Lincoln, and Nye Counties.

During the closure phase, fossil-fuel use would be between 5.1 million and 6.6 million liters (1.3 million and 1.7 million gallons), depending on the repository operating mode. Use during the closure phase would be similar to that for the construction phase.

Hydraulic oils and lubricants and non-fuel hydrocarbons would be used to support operation of equipment during all phases of the project. The quantities of these materials used would range from about 20 million to about 70 million liters (5.3 and 18 million gallons). Because these materials would be recycled and reused, they are not considered in terms of impacts to the environment.

Construction Material

The primary materials needed to construct the repository would be concrete, steel, and copper. Concrete, which consists of cement, sand, aggregate and water, would be used for liners in the main tunnels and ventilation shafts in the subsurface and for the construction of the surface facilities. Aggregate available in the region would be used for concrete and cement would be purchased regionally. The amounts of concrete and cement required are listed in Table 4-39. During the construction phase the amount of concrete required would range from about 420,000 to 500,000 cubic meters (about 550,000 to 650,000 cubic yards), depending on the repository operating mode. For this phase, as much as about 120,000 metric tons (130,000 tons) of steel would be required for a variety of uses including rebar, piping, vent ducts, and track, and 200 to 230 metric tons (220 to 250 tons) of copper for electrical cables. Because the subsurface configuration of the repository would differ for the different operating modes, the relative amount of material used during the initial 5-year construction phase might not be indicative of the amount required to complete the subsurface through the end of development. For example, the amount of steel used during the construction phase for the range of operating modes would be about the same, but the total amount of steel used for the lower-temperature operating mode would be almost twice the amount that would be used for the higher-temperature operating mode.

For the lower-temperature operating mode, which would require the most concrete, the average yearly concrete demand for the construction phase would be about 100,000 cubic meters (about 130,000 cubic yards). The required quantity of concrete would not be expected to affect the regional supply system, which has been able to support the robust construction environment in Las Vegas. The quantities of cement required for the concrete are listed in Table 4-39 because this material would be purchased through regional markets and trucked to the site. This quantity of cement represents less than about 3 percent of the cement consumed in Nevada in 1998 (DIRS 104926-Bauhaus 1998, all).

Because the markets for steel and copper are worldwide in scope, DOE expects little or no impact from increased demand for steel and copper in the region.

The closure phase would require an estimated maximum of 5,000 cubic meters (6,500 cubic yards) of concrete and an estimated maximum of 40 metric tons (44 tons) of steel.

Overall Comparative Impacts

The overall impacts of the repository project in the areas of utilities, energy, and construction material can be compared by evaluating the quantities of these commodities that would be consumed over the life of the project. In general, the quantities of utilities, energy, and materials consumed over the life of the project would be small in comparison to the regional supply capacity, and would be unlikely to affect regional supplies or prices. A major reason for low impacts is the proposed repository schedule for most activities would extend over decades. Even though DOE would build a solar power generating facility on the repository site, it would be necessary to upgrade the transmission lines to the site for the repository to obtain adequate electric power for all the scenarios considered.

Site Services

During the construction phase, DOE would rely on the existing support infrastructure described in Chapter 3, Section 3.1.11.3, during an emergency at the repository. DOE would maintain these capabilities until the project could provide its own services on the site.

The primary onsite response would occur through the onsite Fire Station, Medical Center, and Health Physics facilities after their construction at the North Portal was complete. The Fire Station would maintain fire and rescue vehicles, equipment, and trained professionals to respond to fires, including radiological, mining, industrial, and accident events at the surface and subsurface. The Medical Center would be adjacent to the Fire Station, and would maintain a full-time doctor and nurse and medical supplies to treat emergency injuries and illnesses. These facilities would have the capability to provide complete response to most onsite emergencies. DOE would coordinate the operation of these facilities with facilities at the Nevada Test Site and in the surrounding area to increase response capability, if necessary.

A site security and safeguards system would include the surveillance and safeguards functions required to protect the repository from unauthorized intrusion and sabotage. The system would include the site security barriers, gates, and badging and automated surveillance systems operated by trained security officers. Support for repository security would be available from the Nevada Test Site security force and the Nye County Sheriff's Department, if needed.

The emergency response system would provide responses to accident conditions at or near the repository site. The system would maintain emergency and rescue equipment, communications, facilities, and trained professionals to respond to fire, radiological, mining, industrial, and general accidents above or below ground.

The planned onsite emergency facilities should be able to respond to and mitigate most onsite incidents, including underground incidents, without outside support. Therefore, there would be no meaningful impact to the emergency facilities of surrounding communities or counties.

4.1.12 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

This section describes the management of the radioactive and nonradioactive waste that DOE would generate as a result of performance confirmation, construction, operation and monitoring, and closure activities. The range of operating modes would generate different quantities of waste.

The evaluation of waste management impacts considered the quantities of nonhazardous industrial, sanitary, hazardous, mixed, and radioactive wastes that repository-related activities would generate. Estimated waste quantities are presented in Tables 4-40 through 4-44 in Sections 4.1.12.2 and 4.1.12.4. These estimates were based on construction and operating experience, engineering data, water use estimates, material use estimates, and number of workers. The evaluation assessed these quantities against current public and private capacity to treat and dispose of wastes.

4.1.12.1 Waste and Materials Impacts from Preconstruction Testing and Performance Confirmation

DOE expects preconstruction testing and performance confirmation activities to generate waste similar to and in about the same quantities as that generated during characterization activities with the exception that low-level radioactive waste would be generated in minimal quantities (DIRS 104508-CRWMS M&O 1999, p. 17). Based on 1997 waste generation reports, preconstruction testing and performance confirmation activities should produce about 3,200 cubic meters (110,000 cubic feet) of nonhazardous construction debris and sanitary and industrial solid waste (DIRS 104952-Sygitowicz 1998, pp. 2 and 4) and about 170 kilograms (380 pounds) (volume measurements were not available) of hazardous waste (DIRS 104882-Harris 1998, pp. 3 through 6) that would require disposal. In addition, other waste would be recycled rather than disposed. Wastewater would be generated from runoff, subsurface activities, restrooms, and change rooms.

WASTE TYPES

Construction/demolition debris: Discarded solid wastes resulting from the construction, remodeling, repair, and demolition of structures, road building, and land clearing that are inert or unlikely to create an environmental hazard or threaten the health of the general public. Such debris from repository construction would include such materials as soil, rock, masonry materials, and lumber.

Industrial wastewater: Liquid wastes from industrial processes that do not include sanitary sewage. Repository industrial wastewater would include water used for dust suppression, rinsewater from concrete production and transport, and process water from building heating, ventilation, and air conditioning systems.

Low-level radioactive waste: Radioactive waste that is not classified as high-level radioactive waste, transuranic waste, byproduct material containing uranium or thorium from processed ore, or naturally occurring radioactive material. The repository low-level radioactive waste would include such wastes as personal protective clothing, air filters, solids from the liquid low-level radioactive waste treatment process, radiological control and survey waste, and possibly used canisters (dual-purpose).

Sanitary sewage: Domestic wastewater from toilets, sinks, showers, kitchens, and floor drains from restrooms, change rooms, and food preparation and storage areas.

Sanitary and industrial solid waste: Solid waste that is neither hazardous nor radioactive. Sanitary waste streams include paper, glass, and discarded office material. State of Nevada waste regulations identify this waste stream as *household waste*.

Hazardous waste: Waste designated as hazardous by the Environmental Protection Agency or State of Nevada regulations. Hazardous waste, defined under the Resource Conservation and Recovery Act, is waste that poses a potential hazard to human health or the environment when improperly treated, stored, or disposed of. Hazardous wastes appear on special Environmental Protection Agency lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity. Hazardous waste streams from the repository could include certain used rags and wipes contaminated with solvents.

DOE would use current (as described in Chapter 3, Section 3.1.12) or similar methods to handle the waste streams generated by its preconstruction testing and performance confirmation activities. It would also use offsite landfills to dispose of solid waste and construction debris; accumulate and consolidate hazardous waste and transport it off the site for treatment and disposal; treat and reuse wastewater; and treat and dispose of sanitary sewage. Based on site characterization experience, these activities would result in only small impacts to the regional waste disposal capacity.

4.1.12.2 Waste and Materials Impacts from Construction, Operation and Monitoring, and Closure

The construction phase would generate nonhazardous, nonradioactive wastes and some hazardous waste from the use of such materials as resins, paints, and solvents. Nonhazardous, nonradioactive wastes would include sanitary and industrial solid wastes, construction debris, industrial wastewater, and sanitary sewage. Table 4-40 lists the estimated quantities of waste that the construction phase would generate. These estimates are based on construction experience, water use estimates, and Yucca Mountain Site Characterization Project experience with wastewater generation from dust suppression.

Table 4-40. Waste quantities generated during the construction phase.

	Operating mode	
Waste type	Higher-temperature	Lower-temperature
Construction debris (cubic meters)[a]	5,000	5,000 - 9,300
Hazardous (cubic meters)	1,200	1,200 - 2,300
Sanitary and industrial solid (cubic meters)	11,000	12,000
Sanitary sewage (million liters)[b]	180	180
Industrial wastewater (million liters)	46	55 - 59

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. To convert liters to gallons, multiply by 0.26418.

DOE could use existing Nevada Test Site landfills to dispose of nonrecyclable construction debris and sanitary and industrial solid waste. However, as part of the Proposed Action, DOE would construct a State-permitted landfill on the Yucca Mountain site to dispose of nonrecyclable construction debris and sanitary and industrial solid waste. Section 2.1.2.1.4.3 describes the landfill. If the repository generates construction and demolition debris and sanitary and industrial waste beyond the capacity of this landfill, the excess nonhazardous waste would be disposed of at Nevada Test Site landfills. As listed in Table 4-40, DOE estimates a maximum of 9,300 cubic meters (330,000 cubic feet) of construction debris. If the Department chose not to build a landfill at the repository site, it could ship construction debris to the Test Site's Area 9 U10C Landfill, which has a disposal capacity of 990,000 cubic meters (35 million cubic feet) (DIRS 101811-DOE 1996, p. 4-37). The disposal of construction debris generated during the construction phase would consume less than 1 percent of the disposal capacity in this landfill. DOE could also ship repository-generated sanitary and industrial solid waste to the Test Site for disposal in the Area 23 landfill, which has a capacity of 450,000 cubic meters (16 million cubic feet) (DIRS 101811-DOE 1996, p. 4-37). The disposal of the maximum of 12,000 cubic meters (420,000 cubic feet) of sanitary and industrial solid waste generated during the construction phase at the Area 23 landfill would use less than 3 percent of the disposal capacity.

DOE would package hazardous waste and ship it off the site for treatment and disposal. The Department could continue to dispose of such waste in conjunction with the Nevada Test Site, which has contracts with commercial facilities, or could contract separately with the same or another commercial facility. No more than 2,300 cubic meters (81,000 cubic feet) of hazardous waste (see Table 4-40), weighing 2,300 metric tons (2,500 tons), would be generated during the construction phase. By comparison, 44,000 metric tons (48,000 tons) of hazardous waste was managed in Nevada in 1999 (DIRS 156935-EPA 2001, pp. ES-7). Regional capacity for treatment and disposal of hazardous waste is much greater than the quantity that would be generated at Yucca Mountain. For example, the hazardous waste incineration capacity in western states through 2013 has been estimated at seven times the demand for this service (DIRS 103245-EPA 1996, pp. 32, 33, 35, 46, 47, and 50). The landfill capacity for hazardous waste disposal would be about 50 times the demand. Therefore, the impact on regional hazardous waste capacity from repository-generated hazardous waste during the construction phase would be very small.

DOE would treat and dispose of sanitary sewage and industrial wastewater at onsite facilities. Sanitary sewage from the North Portal Operations Area would go to an existing septic system. The Department would install another septic system to dispose of sanitary sewage from the South Portal Development Area. The industrial wastewater from surface facilities would flow to an evaporation pond at the North Portal Operations Area and wastewater from the subsurface would flow to an evaporation pond at the South Portal Development Area. Sludge would accumulate in the North Portal Operations Area evaporation pond so slowly that DOE would not need to remove it before the closure of the pond (DIRS 102599-CRWMS M&O 1998, pp. 65 to 67). The accumulated sludge at the South Portal Development Area evaporation pond, which would consist of mined rock, portland cement, and fine aggregate, would be removed as needed and added to the excavated rock pile (DIRS 104910-Koppenaal 1998, p. 3). In addition, under the lower-temperature operating mode with surface aging, DOE would install a small evaporation pond for rinsewater from the concrete batch plant as needed.

Activities during the operation and monitoring phase would generate radioactive and nonradioactive wastes and wastewaters and some hazardous waste. DOE does not expect to generate mixed waste. However, repository facilities would have the capability to package and temporarily store mixed waste that operations could generate under unusual circumstances. In addition, the medical clinic would generate a small amount of medical waste that DOE would dispose of in accordance with applicable Federal and State of Nevada requirements. Table 4-41 lists the estimated total waste quantities for repository activities associated with the operation and monitoring phase. These estimates do not include used solar panels because DOE anticipates that recycling options would be available by the time the first solar panels would require replacement, about 2030. Solar panel replacement once every 20 years (DIRS 153882-Griffith 2001, p. 8) would generate about 350 metric tons (390 tons) of material for recycling. Replacement would occur 4 to 16 times, depending on the operating mode.

Table 4-41. Waste quantities generated during the operation and monitoring phase.

	Operating mode	
Waste type	Higher-temperature	Lower-temperature
Low-level radioactive (cubic meters)[a]	68,000	68,000 - 91,000
Hazardous (cubic meters)	6,100	5,600 - 6,300
Sanitary and industrial solid (cubic meters)	81,000	91,000 - 150,000
Sanitary sewage(million liters)[b]	1,800	2,100 - 3,200
Industrial wastewater (million liters)	900	850 - 980

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. To convert liters to gallons, multiply by 0.26418.

Major waste-generating activities during the operation and monitoring phase would include the receipt and packaging of spent nuclear fuel and high-level radioactive waste and continued development of subsurface emplacement areas. Differences in nonradioactive waste quantities from subsurface activities would be due to the different workforce sizes, main drift lengths, and emplacement spacing. Operating mode differences would affect the volumes of hazardous and low-level radioactive wastes generated at the surface facilities as a result of differences in handling the spent nuclear fuel and high-level radioactive waste, and of phase length if waste was aged on the surface. In addition, waste would be generated in personnel areas such as change rooms, restrooms, and offices. If dual-purpose canisters were used and not recycled, the low-level radioactive waste from the canisters would amount to an estimated 29,000 cubic meters (1,000,000 cubic feet) with an estimated weight of 150,000 metric tons (170,000 tons).

However, the total amount of low-level radioactive waste expected using dual-purpose canisters even with the canisters being disposed of rather than recycled would not exceed the amount listed in Table 4-41, which represents the amount expected from the receipt of uncanistered spent nuclear fuel. DOE could decide to recycle the canisters if doing so would be more protective of the environment and more cost effective than direct disposal. Recycling would require melting and recasting of the canister metal to enable other uses.

Monitoring and maintenance activities after the completion of emplacement would also generate wastes, but in much smaller quantities. The first few years after the completion of emplacement would generate greater quantities of waste due to the decontamination and decommissioning of surface nuclear facilities. DOE estimates as much as 700 cubic meters (25,000 cubic feet) of low-level radioactive waste and as much as 280 cubic meters (9,900 cubic feet) of hazardous waste from this activity.

Monitoring and maintenance activities for 76 years under the higher-temperature operating mode would generate a maximum of about 20,000 cubic meters (710,000 cubic feet) of sanitary and industrial solid waste and about 430 million liters (110 million gallons) of sanitary sewage. Monitoring and maintenance activities for 300 years under the lower-temperature operating mode would generate a maximum of about 84,000 cubic meters (about 2.9 million cubic feet) of sanitary and industrial solid waste and about 1.8 billion liters (480 million gallons) of sanitary sewage. Monitoring for periods bounded by these timeframes would generate the same wastes in proportional quantities.

DOE would treat low-level radioactive waste in the Waste Treatment Building (see Section 2.1.2.1.1.3). After treatment, DOE would need to dispose of an estimated maximum 91,000 cubic meters (3.2 million cubic feet) of low-level radioactive waste generated during emplacement activities and the decontamination of surface nuclear facilities. This waste would be disposed of at the Nevada Test Site. The Test Site accepts low-level radioactive waste for disposal from other DOE sites. It has an estimated total disposal capacity of 3.7 million cubic meters (130 million cubic feet) (DIRS 155856-DOE 2000, Table 4-1) (see Section 3.1.12). The reserve capacity (the total capacity reduced by the volume projected to be needed for disposal of other DOE low-level radioactive waste) is 2.6 million cubic meters (92 million cubic feet) (DIRS 155856-DOE 2000, Table 4-1). The impact to the reserve capacity at the Nevada Test Site from the disposal of repository low-level radioactive waste would be 3.5 percent.

During the operation and monitoring phase DOE would dispose of sanitary sewage and industrial wastewater in the onsite wastewater systems and sanitary and industrial solid waste in the onsite landfill or at the Nevada Test Site. The sanitary sewage disposal system would be able to handle the estimated daily sewage flows, and the industrial wastewater facilities would be able to handle the estimated annual wastewater flows. DOE would use the onsite landfill to dispose of sanitary and industrial solid waste, or it could use the existing Nevada Test Site landfill in Area 23 to dispose of such waste. The Area 23 landfill has an estimated 100-year capacity for the disposal of waste generated at the Test Site (DIRS 101803-DOE 1995, p. 9); the addition of repository-generated waste during the operation and monitoring phase would necessitate its expansion.

During the operation and monitoring phase repository-generated hazardous waste would be shipped off the site for treatment and disposal in a permitted facility. DOE would need to dispose of an estimated maximum of 6,300 cubic meters (220,000 cubic feet) of hazardous waste generated by emplacement activities and the decontamination of surface facilities. The estimated maximum annual rate of hazardous waste treatment or disposal would be about 280 cubic meters (9,900 cubic feet), weighing 270 metric tons (300 tons). This peak annual volume is 1 percent of the volume of hazardous waste that was managed in Nevada in 1999. At present, a number of commercial facilities are available for hazardous waste treatment and disposal, and DOE expects similar facilities to be available until the closure of the repository. Regional capacity for treatment and disposal of hazardous waste is much greater than the quantity that would be generated at Yucca Mountain. For example, the estimated hazardous waste incineration capacity in western states through 2013 is seven times the demand for this service (DIRS 103245-EPA 1996, pp. 32, 33, 35, 46, 47, and 50). The landfill capacity for hazardous waste disposal would be about 50 times the demand. Therefore, the impact on regional hazardous waste capacity from repository-generated hazardous waste during the operation and monitoring phase would be very small.

If unusual activities generated mixed waste, DOE would package such waste for offsite treatment and disposal. The estimated maximum annual quantity would be about 1.3 cubic meter (46 cubic feet), which would have a very small impact on the receiving facility. At present, there is commercial capacity (for example, at Envirocare of Utah, with which the Department has a contract for the treatment and disposal of mixed waste). DOE is also pursuing a permit for a mixed waste disposal facility at the Nevada Test Site that would accept mixed waste from other DOE sites for disposal. This facility has a planned capacity of 20,000 cubic meters (710,000 cubic feet) (DIRS 155856-DOE 2000, p. 2-32).

Closure activities, such as the final decontamination and demolition of the repository structures and the restoration of the site, would generate waste and recyclable materials. Table 4-42 lists estimated waste quantities for the closure phase. The ranges of quantities result from more waste generated from more years to complete closure and differences in surface facilities.

Table 4-42. Waste quantities generated during the closure phase.

	Operating mode	
Waste type	Higher temperature	Lower temperature
Demolition debris (cubic meters)[a]	220,000	220,000 - 440,000
Hazardous (cubic meters)	1,200	1,100 - 1,200
Sanitary and industrial (cubic meters)	9,500	9,300 - 12,000
Sanitary sewage (million liters)[b]	160	170 - 250
Industrial wastewater (million liters)	70	77 - 120
Low-level radioactive (cubic meters, after treatment)	3,500	3,200 - 4,600

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. To convert liters to gallons, multiply by 0.26418.

DOE would dispose of demolition debris and sanitary and industrial solid waste in the onsite landfill (or at the Nevada Test Site), and sanitary sewage and industrial wastewater in the onsite septic systems and industrial wastewater system. After disposing of the waste and wastewater, DOE would close the landfill and evaporation ponds in a manner that met applicable requirements.

The Nevada Test Site landfills would have to continue operating past their estimated lives and to expand as needed. The Area 9 U10C Landfill, which accepts demolition debris, has an estimated 70-year operational life; the Area 23 landfill, which is used for sanitary and industrial solid waste disposal, has a 100-year estimated life (DIRS 101803-DOE 1995, pp. 8 and 9).

DOE would continue to dispose of hazardous and low-level radioactive wastes off the site. The Department would ship hazardous waste to an offsite vendor with the appropriate permits and available treatment and disposal capacity. The available capacity for hazardous waste treatment and disposal in the western states would far exceed the demand for many years to come (DIRS 103245-EPA 1996, pp. 32, 33, 36, 46, 47, and 50). Therefore, hazardous waste generated during closure activities would be likely to have a very small impact on the capacity for treatment and disposal at commercial facilities. DOE would ship low-level radioactive waste to a Nevada Test Site disposal facility. The disposal of low-level radioactive waste generated during repository closure at the Nevada Test Site would affect the reserve disposal capacity about two-tenths of 1 percent.

Main Index Vol 1 Index

Overall Impacts to Waste Management

The overall impact of managing the Yucca Mountain repository waste streams would differ little among the operating modes, in part because DOE would build onsite facilities to accommodate construction and demolition debris, sanitary and industrial solid wastes, sanitary sewage, and industrial wastewater. Although such activities are not currently planned, the use of existing Nevada Test Site landfills for the disposal of construction and demolition debris and sanitary and industrial solid waste would require the continuation of the operation of these facilities past their estimated lifetimes of 70 and 100 years (DIRS 101803-DOE 1995, pp. 8 and 9). Such use would probably require the expansion of landfill capacities. Use of the Nevada Test Site U10C landfill for construction and demolition debris would require at least 61 percent of the reserve capacity, and could exceed the disposal capacity by 20 percent if 440,000 cubic meters (16 million cubic feet) was to be disposed at the landfill. Use of the Nevada Test Site Area 23 landfill for sanitary and industrial solid waste disposal would use 23 to 37 percent of the disposal capacity. Further review under the National Environmental Policy Act would be completed, as required, to expand capacity of the landfills at the Nevada Test Site.

Repository-generated low-level radioactive and hazardous waste would have little impact at disposal facilities, which could readily accommodate this waste. DOE would use less than 4 percent of the reserve capacity for low-level radioactive waste disposal at the Nevada Test Site. A very small fraction of the existing offsite capacity would be used for repository-generated hazardous waste. The peak annual volume of hazardous waste would be 1 percent of the volume of hazardous waste managed in Nevada in 1999, when the State ranked fortieth in the Nation for the amount of hazardous waste managed (DIRS 156935-EPA 2001, p. ES-7). Nationally, hazardous waste treatment and disposal facilities received 6.0 million metric tons (6.6 million tons) of hazardous waste in 1999 (DIRS 156935-EPA 2001, p. ES-10). As noted above, the projected available capacity through 2013 for treatment and disposal of hazardous waste greatly exceeds demand. The impact to hazardous waste treatment and disposal capacity from repository-generated hazardous waste would be very small.

Table 4-43 lists waste quantities generated for the higher-temperature operating mode and the range of estimated waste quantities for the lower-temperature operating mode for all phases. If not recycled, dual-purpose canisters would add an estimated 29,000 cubic meters (1,000,000 cubic feet) of low-level waste.

Table 4-43. Total waste quantities generated for all phases.[a]

Waste type	Operating mode	
	Higher-temperature	Lower-temperature[b]
Construction and demolition debris (cubic meters)[c]	220,000	220,000 - 440,000
Hazardous (cubic meters)	8,400	8,400 - 8,900
Sanitary and industrial solid (cubic meters)	100,000	110,000 - 170,000
Sanitary sewage (million liters)[d]	2,100	2,400 - 3,600
Industrial wastewater (million liters)	1,000	990 - 1,200
Low-level radioactive (cubic meters after treatment)	71,000	71,000 - 95,000

a. Totals for the construction, operation and monitoring, and closure phases.
b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
c. To convert cubic meters to cubic feet, multiply by 35.314.
d. To convert liters to gallons, multiply by 0.26418.

4.1.12.3 Impacts from Hazardous Materials

The operation of the Yucca Mountain Repository would require the use of hazardous materials including paints, solvents, adhesives, sodium hydroxide, dry carbon dioxide, aluminum sulfate, sulfuric acid, and compressed gases. DOE has programs and procedures in place to procure and manage hazardous materials (DIRS 104842-YMP 1996, all), ensuring their procurement in the appropriate quantities and storage under the proper conditions. At the repository, DOE would use an automated inventory management program (DIRS 104508-CRWMS M&O 1999, p. 62) to control and track inventory.

4.1.12.4 Waste Minimization and Pollution Prevention

DOE would develop a waste minimization and pollution prevention awareness plan similar to the plan it has used during site characterization activities at Yucca Mountain (DIRS 103203-YMP 1997, all). The goal of this new plan would be to minimize quantities of generated waste and to prevent pollution. To achieve this goal, DOE would establish requirements for each onsite organization and identify methods and activities to reduce waste quantities and toxicity.

DOE would recycle materials to the extent that it was cost-effective, feasible, and environmentally sound. Table 4-44 lists estimated quantities of materials that DOE would recycle during the life of the repository.

Table 4-44. Total recyclable material quantities generated for all phases.[a]

	Operating mode	
Material	Higher-temperature	Lower-temperature[b]
Recyclables (cubic meters)[c,d]	230,000	260,000 - 370,000
Steel (metric tons)[e]	51,000	51,000 - 240,000
Dual-purpose canisters[f] (cubic meters)	29,000	29,000
Oils and lubricants (liters)[g]	22 million	34 million - 67 million
Solar panels (metric tons)	1,700	1,700 - 5,700

a. Total for construction, operation and monitoring, and closure phases.
b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
c. Nonhazardous, nonradioactive materials such as paper, plastic, glass, and nonferrous metals.
d. To convert cubic meters to cubic feet, multiply by 35.314.
e. To convert metric tons to tons, multiply by 1.1023.
f. If dual-purpose canisters were used they would be recycled if appropriate, with regard to protection of the environment and cost-effectiveness. Estimated weight is 150,000 metric tons.
g. To convert liters to gallons, multiply by 0.26418.

DOE has identified pollution prevention opportunities in the repository conceptual design process. The Waste Treatment Building design includes recycling facilities for the large aqueous low-level radioactive waste stream [690,000 liters (182,000 gallons) per year for the uncanistered packaging scenario] (DIRS 100248-CRWMS M&O 1997, p. 23) that would result from decontamination activities. Wastewater recycling would greatly reduce water demand by repository facilities, as well as the amount of wastewater that would otherwise require disposal. In addition, DOE would use practical, state-of-the-art decontamination techniques such as pelletized solid carbon dioxide blasting that would generate less waste than other techniques.

In addition, DOE would use automated maintenance tracking and inventory management programs that would interface with the procurement system (DIRS 104508-CRWMS M&O 1999, p. 62). These systems would assist in ensuring the proper maintenance of equipment through a preventive maintenance approach, which could lead to less waste generation. Inventory management would prevent overstocking that could allow chemicals and other items to exceed their shelf lives and become waste.

4.1.13 ENVIRONMENTAL JUSTICE

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,* directs Federal agencies to identify and address the potential for their activities to cause disproportionately high and adverse impacts to minority or low-income populations. This section uses the results of analyses from other disciplines and consideration of unique exposure pathways, sensitivities, and cultural practices to determine if disproportionately high and adverse impacts to human health or the environment of minority or low-income populations are likely to occur from repository performance confirmation, construction, operation and monitoring, and closure activities.

4.1.13.1 Methodology and Approach

DOE performs environmental justice analyses to identify whether any high and adverse impacts would fall disproportionately on minority and low-income populations. The potential for environmental justice concerns exists if the following could occur:

- *Disproportionately high and adverse human health effects:* Adverse health effects would be risks and rates of exposure that could result in latent cancer fatalities and other fatal or nonfatal adverse impacts to human health. *Disproportionately high and adverse human health effects* occur when the risk or rate for a minority or low-income population from exposure to a potentially large environmental hazard appreciably exceeds or is likely to appreciably exceed the risk to the general population and, where available, to another appropriate comparison group (DIRS 103162-CEQ 1997, all).

- *Disproportionately high and adverse environmental impacts to minority or low-income populations:* An adverse environmental impact is one that is unacceptable or above generally accepted norms. A disproportionately high impact is an impact (or the risk of an impact) to a low-income or minority community that significantly exceeds the corresponding impact to the larger community (DIRS 103162-CEQ 1997, all).

The approach to environmental justice analysis first brings together the results of analyses from different technical disciplines that focus on consequences to certain resources, such as air, land use, socioeconomics, air quality, noise, and cultural resources, that in turn could affect human health or the environment. On the basis of these analyses, DOE identified potential impacts on the general population. Second, based on available information, the approach assesses whether there are unique exposure pathways, sensitivities or cultural practices that would result in different impacts on minority or low-income populations. If potential impacts identified under either assessment would be high and adverse, the approach then compares the impacts on minority and low-income populations to those on the general population to determine whether any high and adverse impacts fall disproportionately on minority and low-income populations. In other words, if high and adverse impacts on a minority or low-income population would not appreciably exceed the same type of impacts on the general population, no disproportionately high and adverse impacts would be expected. In making these determinations, DOE considers geographical areas that contain high percentages of minority or low-income populations as reported by the Bureau of the Census. As discussed in Chapter 3, Section 3.1.13, DOE used 2000 Census data for minority populations and 1990 Census data for low-income populations as the best, readily available information that would allow identification of the minority and low-income populations.

The EIS definition of a minority population is in accordance with the basic racial and ethnic categories reported by the Bureau of the Census. A minority population is one in which the percent of the total population comprised of a racial or ethnic minority is meaningfully greater than the percent of such groups in the total population [for this EIS, a minority population is one in which the percent of the total population comprised of a racial or ethnic minority is 10 percentage points or more higher than the percent of such groups in the total population (DIRS 103162-CEQ 1997, all)]. Nevada had a minority population of 34.8 percent in 2000. For this EIS, therefore, one focus of the environmental justice analysis is the potential for construction, operation and monitoring, and closure of the proposed repository to have disproportionately high and adverse impacts on the populations in census tracts in the region of influence (principally in Clark, Nye, and Lincoln Counties) having a minority population of 44.8 percent or higher.

Nevada had a low-income population of 10 percent in 1990. Using the approach described in the preceding paragraph for minority populations, a low-income population is one in which 20 percent or more of the persons in a census block group live in poverty, as reported by the Bureau of the Census in accordance with Office of Management and Budget requirements (DIRS 148189-Bureau of the Census 1999, all). Therefore, the second focus of the environmental justice analysis for this EIS is the potential for construction, operation and monitoring, and closure of the proposed repository to have disproportionately high and adverse impacts on the populations in census block groups having a low-income population of 20 percent or higher.

In response to public comments, DOE has reevaluated available information to determine whether the Draft EIS overlooked any unique exposure pathways or unique resource uses that could create opportunities for disproportionately high and adverse impacts to minority and low-income populations, even though the impacts to the general population would not be high and adverse. Several unique pathways or resources were identified and analyzed, although none revealed a potential for disproportionately high and adverse impacts (see Section 4.1.13.2).

4.1.13.2 Preconstruction Testing and Performance Confirmation, Construction, Operation and Monitoring, and Closure

Cultural Resources

DOE has implemented a worker education program on the protection of these resources to limit direct impacts to cultural resources, especially inadvertent damage and illicit artifact collecting. If significant data recovery (artifact collection) were required during construction and operation, DOE would initiate additional consultations with Native American Tribes to determine appropriate involvement. Further, archaeological resources and potential data recovery would be managed and conducted through consultations with the State Historic Preservation Officer or the Advisory Council on Historic Preservation.

Public Health and Safety

The EIS analyses determined that the impacts that could occur to public health and safety would be small on the population as a whole for all phases of the Proposed Action, and that no subsections of the population, including minority or low-income populations, would receive disproportionate impacts. The analysis considered an area that included Timbisha Shoshone Trust lands near Scottys Junction, Nevada.

Because contamination of edible plants and animals would be unlikely from construction, operation and monitoring, and eventual closure of the repository, impacts to persons leading subsistence lifestyles would be unlikely. During the period of construction, operation and monitoring, and closure of the proposed repository, the only radionuclides expected to be released would be naturally occurring radon and radon decay products, and noble gases. Of these, only radon decay products have the potential to accumulate in the environment in the edible portions of wild animals that might live within the land withdrawal area and later be consumed. DOE estimated the potential health impacts from a subsistence diet based primarily on game taken from lands proximate to the repository exclusion areas. DOE calculated the consequences of a 100 kilograms per year (approximately 220 pounds per year or 10 to 11 ounces per day over a year) ingestion of animals that had hypothetically experienced radon uptake. For the peak year, DOE calculated a 0.4 millirem increase in dose, which would have no adverse health effects. DOE concluded that no disproportionately high and adverse health and safety impacts would be likely. DOE also reviewed data on the potential for radioactive uptake from consumption of piñon nuts (DIRS 156058-Fresquez et al. 2000, all). Because piñon pine nuts are produced irregularly in 7- to 10-year cycles and radionuclide concentrations are very low in piñon pine trees and their edible portions,

Main Index Vol 1 Index

DOE concluded there would be little potential health impact. There would be no disproportionately high and adverse health and safety impacts.

Land Use

Direct land-use impacts from the Proposed Action would be low on members of the public because of the existing restriction on site access for most affected areas. There are no communities with high percentages of minority or low-income populations within the region of influence (see Chapter 3, Table 3-1).

Air Quality

Impacts to air quality from the Proposed Action would be small. Furthermore, DOE would use best management practices for all activities, particularly ground-disturbing activities that could generate fugitive dust and construction activities that could produce vehicle emissions. The analysis considered an area that included Timbisha Shoshone Trust lands near Scottys Junction, Nevada.

Biological Resources and Soils

Impacts to biological resources and soils would be low to nonexistent. Consequences for any resources of importance to minority or low-income communities would be small.

Socioeconomics

Because of the large population and employment in the region of influence, socioeconomic impacts from repository construction and operation would be small. During the construction phase and the operation and monitoring phase, regional employment would increase less than 0.5 percent above the baseline level (see Section 4.1.6.2.1). Changes to the baseline regional population would not be greater than 0.5 percent through 2033. The Proposed Action would generate minimal impacts to employment and population. Potential socioeconomic impacts of all other economic parameters analyzed (Gross Regional Product, real disposable income, and expenditures by State and local governments) would be small.

Noise

Impacts to sensitive noise receptors from the Proposed Action would not be likely because no sensitive noise receptors live in the Yucca Mountain region. Furthermore, there are no low-income or minority communities adjacent to the site.

4.1.13.3 Environmental Justice Impact Analysis Results

This analysis uses information from Sections 4.1.1 through 4.1.12. Those sections address impacts from all active phases of the Proposed Action—construction, operation and monitoring, and closure. As noted above, DOE expects that the impacts of the Proposed Action would be small on the population as a whole. DOE has not identified any subsection of the population, including minority and low-income populations, that would receive disproportionate impacts, and no unique exposure pathways, sensitivities, or cultural practices that would expose minority or low-income populations to disproportionately high and adverse impacts. Accordingly, DOE has concluded that no disproportionately high and adverse impacts would result from the Proposed Action.

4.1.13.4 A Native American Perspective

Native American tribal governments have a special and unique legal and political relationship with the Government of the United States, as established by treaty, statute, legal precedent, and the U.S. Constitution. For this reason DOE will continue to consult with tribal governments and will continue to work with representatives of the Consolidated Group of Tribes and Organizations to ensure the consideration of tribal rights and concerns before making decisions or implementing programs that affect such tribes; to continue the protection of Native American cultural resources, sacred sites, and potential traditional cultural properties; and to implement any appropriate mitigation measures.

In reaching the conclusion that there would be no disproportionately high and adverse impacts on minorities or low-income populations, DOE acknowledges that people from many Native American tribes have used the area proposed for the repository as well as nearby lands (DIRS 102043-AIWS 1998, p. 2-1), that the lands around the site contain cultural, animal, and plant resources important to those tribes, and that the implementation of the Proposed Action would continue restrictions on free access to the repository site. DOE acknowledges that Native American people living in the Yucca Mountain vicinity have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action.

Native American people living in the Yucca Mountain vicinity hold views and beliefs about the relationship between the proposed repository and the surrounding region that they have expressed in *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (DIRS 102043-AIWS 1998, all). Concerning the approach to daily life, the authors of that document, who represent the Western Shoshone, Owens Valley Paiute and Shoshone, Southern Paiute, and other Native American organizations, state:

> *…we have the responsibility to protect with care and teach the young the relationship of the existence of a nondestructive life on Mother Earth. This belief is the foundation for our holistic view of the cultural resources, i.e., water, animals, plants, air, geology, sacred sites, traditional cultural properties, and artifacts. Everything is considered to be interrelated and dependent on each other to sustain existence (DIRS 102043-AIWS 1998, p. 2-9).*

The authors discuss the cultural significance of Yucca Mountain lands to Native American people:

> *American Indian people who belong to the CGTO (Consolidated Group of Tribes and Organizations) consider the YMP lands to be as central to their lives today as they have been since the creation of their people. The YMP lands are part of the holy lands of Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone people (DIRS 102043-AIWS 1998, p. 2-20).*

and:

> *The lack of an abundance of artifacts and archaeological remains does not infer that the site was not used historically or presently and considered an integral part of the cultural ecosystem and landscape (DIRS 102043-AIWS 1998, p. 2-10).*

The authors address the continuing denial of access to Yucca Mountain lands:

> *One of the most detrimental consequences to the survival of American Indian culture, religion, and society has been the denial of free access to their traditional lands and resources (DIRS 102043-AIWS 1998, p. 2-20).*

and:

> *No other people have experienced similar cultural survival impacts due to lack of free access to the YMP area (DIRS 102043-AIWS 1998, p. 2-20).*

The authors recognize that past restrictions on access have resulted in generally beneficial and protective effects for cultural resources, sacred sites, and potential traditional cultural properties (DIRS

102043-AIWS 1998, Section 3.1.1). However, the authors express concerns of Native American people regarding use of the repository:

> *The past, present, and future pollution of these holy lands constitutes both Environmental Justice and equity violations. No other people have had their holy lands impacted by YMP-related activities (DIRS 102043-AIWS 1998, p. 2-20).*

and:

> *Access to culturally significant spiritual places and use of animals, plants, water and lands may cease because Indian people's perception of health and spiritual risks will increase if a repository is constructed (DIRS 102043-AIWS 1998, p. 3-1).*

Even after closure and reclamation, the presence of the repository would represent an irreversible impact to traditional lands and other elements of the natural environment in the view of Native American people.

Regarding the transportation of spent nuclear fuel and high-level radioactive waste, the authors state:

> *…health risks and environmental effects resulting from the construction and operation of the proposed intermodal transfer facility (ITF) and the transportation of high-level waste and spent nuclear fuel is considered by Indian people to be disproportionately high. This is attributed primarily to the consumption patterns of Indian people who still use these plants and animals for food, medicine, and other related cultural or ceremonial purposes (DIRS 102043-AIWS 1998, p. 2-19).*

and:

> *The anticipated additional noise and interference associated with an ITF* [Intermodal Transfer Facility] *and increased transportation may disrupt important ceremonies that help the plants, animals, and other important cultural resources flourish, or may negatively impact the solitude that is needed for healing or praying (DIRS 102043-AIWS 1998, p. 2-19).*

DOE recognizes that it could not undertake disposal of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain without conflict with the viewpoint expressed in the American Indian Writers Subgroup document, but believes that, should the repository be designated, DOE would have the opportunity to engage in regular consultations with representatives of tribes in the region to identify further measures to protect cultural resources, thereby lessening the concern expressed by Native American people.

4.1.14 IMPACTS OF REPOSITORY OPERATING MODES

This section briefly describes and compares the short-term environmental impacts for the range of repository operating modes considered as part of the Proposed Action. This range includes the higher-temperature operating mode [where postclosure repository temperatures could be above the boiling point of water (96°C, or 205°F) and the lower-temperature operating mode [where postclosure repository temperatures would remain below 85°C (185°F)]. The lower-temperature operating mode also includes a range of operating characteristics, and differences noted below describe the largest potential differences among the operating modes.

In general, the EIS analyses found the lower-temperature operating mode would have higher environmental impacts than the higher-temperature operating mode. At least partly responsible for this is the fact that the duration of the lower-temperature operating mode (171 to 341 years) would be longer than the duration of the higher-temperature operating mode (115 years). Any time-dependent impacts, such as health and safety impacts to populations or energy or material usage, are typically higher for the longer duration lower-temperature operating mode. Overall, impacts would be small. Some areas of specific interest:

- Short-term health and safety impacts to the public would be small, with those of the lower-temperature operating mode 2 to 4 times greater than the higher-temperature operating mode.
- Short-term health and safety impacts to workers would be small, with those of the lower-temperature operating mode up to 60 to 70 percent greater than the higher-temperature operating mode.
- Short-term impacts for the land use, ambient air quality, surface water, groundwater, biological resources and soil, cultural resources, socioeconomics, repository accidents, noise, aesthetics, utilities, energy, materials, waste generation, and environmental justice would be small.

A more complete comparison of potential impacts is shown in Section 2.4 and Table 2-7.

4.1.15 IMPACTS FROM MANUFACTURING REPOSITORY COMPONENTS

This section discusses the potential environmental impacts from the manufacturing of components required by the Proposed Action to dispose of spent nuclear fuel and high-level radioactive waste permanently at a monitored geologic repository at Yucca Mountain. Repository components include disposal containers, emplacement pallets, drip shields, dry storage cask shells, and shipping casks. The solar panels required for the solar power electric generating facility are standard commercially available components that DOE could buy from several vendors. Therefore, there would be no offsite manufacturing environmental impacts specifically attributed to the solar panels. This analysis considers transportation overpacks that would provide radiation shielding in the same manner as a shipping cask but that DOE would use only in conjunction with disposable canisters and dual-purpose canisters to be shipping casks without baskets or other internal configurations.

4.1.15.1 Overview

DOE followed the overall approach and analytical methods used for the environmental evaluation and the baseline data directly from the *Department of the Navy Final Environmental Impact Statement for a Container System for the Management of Naval Spent Nuclear Fuel* (DIRS 101941-USN 1996, all). DOE's evaluation focuses on ways in which the manufacture of the repository components could affect environmental attributes and resources at a representative manufacturing site. It is not site-specific because more than one manufacturer probably would be required to meet the production schedule requirements for component delivery, and the location of the companies chosen to manufacture these components is not known. The companies and, therefore, the actual manufacturing sites would be determined by competitive bidding.

The analysis used a representative manufacturing site based on five facilities that produce casks, canisters, and related hardware for the management of spent nuclear fuel. The concept of a representative site was used in the Navy EIS (DIRS 101941-USN 1996, p. 4-1), and the representative site used in this analysis was defined in the same way, using the same five existing manufacturing facilities with the same attributes. The facilities used to define the representative site are in Westminster, Massachusetts; Greensboro, North Carolina; Akron, Ohio; York, Pennsylvania; and Chattanooga, Tennessee (DIRS 101941-USN 1996, p. 4-17). All of these facilities make components for firms with cask and canister designs approved by the Nuclear Regulatory Commission.

The analysis assumed that the manufacturing facilities and processes being used are similar to the facilities and processes that would produce disposal containers, emplacement pallets, drip shields, dry storage cask shells, and shipping casks for the Yucca Mountain Repository. Although these five facilities

Main Index Vol 1 Index

might not fabricate components from titanium (the material required for the drip shields), the fabrication processes of rolling plate, forming, and welding necessary to produce a drip shield are similar to the processes used to manufacture casks and canisters from other structural material. The estimates for manufacturing time and component cost account for the differences in processing titanium components (for example, welding), so the impacts of manufacturing titanium components could be estimated using the same methods as those used for standard nuclear-grade components. The analysis considered the manufacturing processes used at these facilities and the total number of components required to implement each packaging scenario. Manufacture of all components was assumed to occur at one representative site, but DOE recognizes that it probably would occur at more than one site. The assumption of one manufacturing site is conservative (that is, it tends to overestimate impacts) because it concentrates the potential impacts.

In addition, the analysis of offsite manufacturing evaluated the use of materials and the potential for impacts to material markets and supplies.

Section 4.1.15.3 describes the components to be manufactured offsite. Section 4.1.15.4 discusses pertinent information on environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.15.5 describes environmental impacts on air quality, health and safety, socioeconomics, material use, waste generation, and environmental justice.

4.1.15.2 Components and Production Schedule

Table 4-45 lists the quantities of components analyzed for the higher- and lower-temperature operating modes for canistered and uncanistered packaging scenarios described in Chapter 2, Section 2.1.1. In general, the environmental impacts of offsite manufacturing are bounded by the uncanistered packaging scenario. The impacts of the canistered scenario are also presented to allow canistered and uncanistered comparisons. The only component with higher quantities under canistered scenarios would be rail shipping casks. Table 4-45 includes all repository components for naval spent nuclear fuel that would be emplaced in Yucca Mountain but does not include shipping casks for naval spent nuclear fuel. Shipping casks for naval spent nuclear fuel are owned and managed by the Navy. DIRS 101941-USN (1996, all) analyzed environmental impacts for production of naval spent nuclear fuel canisters and shipping casks. Because naval spent nuclear fuel waste packages represent less than 3 percent of the inventory to be emplaced in the repository, the production of naval spent nuclear fuel casks would add little to the impacts described in the following sections.

Table 4-45. Quantities of offsite-manufactured components for the Yucca Mountain Repository.[a]

		Operating mode/packaging scenario[b]			
		Higher-temperature		Lower-temperature	
Component	Description	UC	C	UC	C
Rail shipping casks or overpacks	Storage and shipment of SNF[c] and HLW[c]	0	92 or 120	0	92 or 120
Legal-weight truck shipping casks	Storage and shipment of uncanistered fuel	120	8	120	8
Disposal containers		11,300	11,300	11,300 - 16,900	11,300 - 16,900
Emplacement pallet	Support for emplaced waste package	11,300	11,300	11,300 - 16,900	11,300 - 16,900
Drip shields	Titanium cover for a waste package	10,500	10,500	11,300 - 15,900	11,300 - 15,900
Solar panels[d]	Photovoltaic solar panels–commercial units	27,000	27,000	27,000	27,000
Dry storage cask shells[e]	Metal shell structure of storage vault for aging	0	0	0 - 4,000	0 - 4,000

a. The number of containers is an approximation but is based on the best available estimates.
b. UC = uncanistered; C = canistered.
c. SNF = spent nuclear fuel; HLW = high-level radioactive waste.
d. Number of panels in use at any one time.
e. Necessary only for commercial spent nuclear fuel and only if DOE used surface aging as part of a lower-temperature operating mode.

As currently planned, all of the components listed in Table 4-45 except drip shields would be manufactured over 24 years to support emplacement in the repository. Manufacturing activity would build up during the first 5 years, then would remain nearly constant through the remainder of the 24-year period. The drip shields would not be needed until the closure of the repository; therefore, the analysis assumed manufacture and delivery of drip shields would not begin until nearly 76 to 300 years after the completion of emplacement. It would take approximately 10 years to manufacture drip shields. The solar power generating facility would be built over a 6-year period beginning in 2005 (DIRS 153882-Griffith 2001, p. 6).

The dry storage cask shells would be needed only if surface aging were to be used in conjunction with the lower-temperature operating mode. Because surface aging would occur in parallel with emplacement, the dry storage cask shells would be manufactured in the same 24-year period as the disposal containers, emplacement pallets, and shipping casks.

4.1.15.3 Components

Disposal Containers

The disposal container would be the final outside container used to package the spent nuclear fuel and high-level radioactive waste emplaced in the repository. The basic design calls for a cylindrical vessel with an outer layer of corrosion-resistant nickel-based alloy (Alloy-22) and an inner liner of stainless steel Type 316NG. The inner and outer lids would be stainless steel Type 316NG and Alloy-22, respectively. An additional Alloy-22 lid would be installed on the closure end. The bottom lids would be welded to the cylindrical body at the fabrication shop, and the top inner and outer lids would be welded in place after the placement of spent nuclear fuel or high-level radioactive waste in the container at the repository. About 10 different disposal container designs would be used for different types of spent nuclear fuel and high-level radioactive waste. The designs would vary in length from 3.6 to 6.1 meters (11.8 to 20 feet) and the outside diameters would range from 1.3 to 2.1 meters (4.3 to 6.6 feet). In addition, the internal configurations of the containers would be different to accommodate different uncanistered spent nuclear fuel configurations and a variety of spent nuclear fuel and high-level radioactive waste disposable canisters. The mass of an empty disposal container would range from about 19 to 33 metric tons (21 to 36 tons). If surface aging was used as part of the lower-temperature operating mode, containers used for aging are assumed to be stainless steel Type 316NG.

Casks for Rail and Legal-Weight Truck Shipments

DOE would use two basic kinds of shipping cask designs—rail and truck—to ship spent nuclear fuel and high-level radioactive waste to the repository. The design of a specific cask would be tailored to the type of material it would contain. For example, rail and truck casks that could be used to ship commercial spent nuclear fuel would be constructed of stainless- or carbon-steel plate materials formed into cylinders and assembled to form inner and outer cylinders (DIRS 101941-USN 1996, p. 4-3 and 4-4). A depleted uranium or lead liner would be installed between the stainless- or carbon-steel cylinders, and a vessel bottom with lead or depleted uranium between the inner and outer stainless- or carbon-steel plates would be welded to the cylinders. A support structure that could contain neutron-absorbing material would be welded into the inner liner, if required. A polypropylene sheath would be placed around the outside of the cylinder for neutron shielding. After spent nuclear fuel assemblies were inserted into the cask, a cover with lead or depleted uranium shielding would be bolted to the top of the cylinder to close and seal it. Transportation overpacks would be very similar in design and construction to shipping casks but would not have an internal support structure for the spent nuclear fuel because they would be used only for dual-purpose or disposable canisters.

For commercial spent nuclear fuel, casks and overpacks are typically 4.5 to 6 meters (15 to 20 feet) long and about 0.5 to 2 meters (1.6 to 6.6 feet) in diameter. These casks are designed to be horizontal when shipped. Empty truck casks typically weigh from 21 to 22 metric tons (about 23 to 24 tons). Empty rail casks (or overpacks) for commercial spent nuclear fuel typically weigh from 59 to 91 metric tons (65 tons to a little over 100 tons). The corresponding weights when loaded with spent nuclear fuel range between 22 and 24 metric tons (24 and 26 tons) for truck casks and between 64 and 110 metric tons (70 and 120 tons) for rail casks. For protection during shipment, large removable impact limiters of aluminum honeycomb or other crushable impact-absorbing material would be placed over the ends (DIRS 101837-JAI 1996, all).

Emplacement Pallets

The emplacement pallet would support the waste packages emplaced and allow end-to-end placement of waste packages to within 10 centimeters (4 inches) of each other. The emplacement pallet would be shorter than the waste package so it would not interfere with close placement. The pallets would be fabricated from Alloy-22 plates welded together to form a V-shaped top surface, which would accept all waste package diameters, and two Alloy-22 supports. Stainless steel Type 316L tubes would connect the two emplacement Alloy-22 supports. Two pallet overall lengths are specified for emplacement support of all waste package designs. The shorter emplacement pallet [2.5 meters (8 feet)] would be used for the waste package containing DOE spent nuclear fuel and high-level radioactive waste and the longer emplacement pallet [4.2 meters (14 feet)] would be used for all other waste package designs. The mass of a short pallet and a long pallet is 1.8 and 2.1 metric tons (2 and 2.2 tons), respectively.

Drip Shields

The drip shield would be a rigid structure designed to divert water away from the waste packages. The drip shield would be fabricated from titanium Grade 7 plates for the water diversion surface, titanium Grade 24 for the structural members, and Alloy-22 for the feet. The Alloy-22 feet would be mechanically attached to the titanium drip shield side plates, since the two materials cannot be welded together. For the higher-temperature operating mode and the lower-temperature operating modes with waste package spacing of less than 1.6 meters (5 feet), a continuous design drip shield would be used. The continuous design drip shield would be installed in sections, with one end designed to overlap and interlock with the opposite end of the previously emplaced drip shield section. The continuous drip shield section would be 6.1 meters (20 feet) long by 2.5 meters (8 feet) wide by 6.1 meters (20 feet) high with a mass of 4.2 metric tons (4.6 tons).

For the lower-temperature operating mode, as waste package spacing increased it might become economical to use a freestanding enclosed drip shield design (DIRS 152808-Skorska 2000, all). The freestanding drip shield would be designed in two lengths, one shorter version [3.9-meter (13-foot) length] for the waste package containing DOE spent nuclear fuel and high-level radioactive waste and one longer version [6.4-meter (20-foot) length] for all other waste package designs. The ends of these drip shields would be partially enclosed. The materials used for the freestanding drip shield design would be the same as for the continuous design drip shield. The mass of a short drip shield and a long drip shield is 3.1 metric tons (3.4 tons) and 4.55 metric tons (5 tons), respectively.

Dry Storage Cask Shells

The dry storage cask shell would be fabricated from carbon steel. The shell would be the portion of the concrete dry storage cask system (used only for surface aging under the lower-temperature operating mode) that would be manufactured offsite. Each shell, which includes a base structure, would be approximately 3.4 meters (11 feet) in diameter by 5.9 meters (19 feet) high and would be made from thick carbon steel plate. Carbon steel plate would be formed into a cylinder to form the shell and carbon plate material would be welded to the shell cylinder to form the base structure of the shell. The shell would weigh about 44 metric tons (49 tons).

4.1.15.4 Existing Environmental Settings at Manufacturing Facilities

Because there are facilities that could meet the projected manufacturing requirements, the assessment concluded that no new construction would be necessary and that there would be no change in land use for the offsite manufacture of repository components. Similarly, cultural, aesthetic, and scenic resources would remain unaffected. Ecological resources, including wetlands, would not be affected because

Main Index Vol 1 Index

existing facilities could accommodate the manufacture of repository components and new or expanded facilities would not be required. Some minor increases in noise, traffic, or utilities would be likely, but none of these increases would result in impacts on the local environment.

Water consumption and effluent discharge during the manufacture of components would be typical of a heavy manufacturing facility and would represent only a small change, if any, from existing rates. Similarly, effluent discharges would not increase enough to cause difficulty in complying with applicable local, state, and Federal regulatory limits, and would be unlikely to result in a discernible increase in pollutant activity.

Accordingly, the following paragraphs contain information on environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.15.5 evaluates the environmental impacts to these resource areas for a representative site.

Air Quality

The analysis evaluated the ambient air quality status of the representative manufacturing location by examining the air quality of the areas in which the reference manufacturing facilities are located. The principal criteria pollutants for cask manufacturing facilities are ozone, carbon monoxide, and particulate matter (PM_{10}). Areas where ambient air quality standards are not exceeded, or where measurements have not been made, are considered to be in attainment. Areas where the air quality violates Federal or state regulations are in nonattainment and subject to more stringent regulations. Typical existing container and cask manufacturing facilities are in nonattainment areas for ozone and in attainment areas for carbon monoxide and particulate matter.

Because most of the existing typical manufacturing facilities are in nonattainment areas for ozone, the analysis assumed that the representative site would be in nonattainment for ozone and that ozone would be the criteria pollutant of interest. Volatile organic compounds and nitrous oxides are precursors for ozone and are indicators of likely ozone production. For the areas in which the reference manufacturing facilities are located, an average of 3,400 metric tons (approximately 3,800 tons) of volatile organic compounds and 39,000 metric tons (approximately 43,000 tons) of nitrous oxides were released to the environment in 1990 (DIRS 101941-USN 1996, p. 4-5).

Health and Safety

Data on the number of accidents and fatalities associated with cask and canister fabrication at the representative manufacturing location were based on national incidence rates for the relevant sector of the economy. In 1992, the occupational fatality rate for the sector that includes all manufacturing was 3 per 100,000 workers; the occupational illness and injury rate for fabricated plate work manufacturing in 1992 was 6.3 per 100 full-time workers (DIRS 101941-USN 1996, p. 4-5).

The manufacture of hardware for each of the operating modes and packaging scenarios would be likely to be in facilities that have had years of experience in rolling, shaping, and welding metal forms, and then fabricating large containment vessels similar to the required repository components for nuclear materials. Machining operations at these facilities would involve standard procedures using established metalworking equipment and techniques. Trained personnel familiar with the manufacture of large, multiwall, metal containment vessels would use the equipment necessary to fabricate such items. Because of this experience and training, DOE anticipates that the injury and illness rate would be equal to or lower than the industry rates.

Socioeconomics

Each of the five manufacturing facilities examined in this analysis is in a Metropolitan Statistical Area or a Primary Statistical Area, as defined by the U.S. Bureau of the Census. The counties comprising each statistical area define the affected socioeconomic environment for each facility. The populations of the affected environments associated with the five facilities ranged from about 373,000 to 1.2 million in 1998 (DIRS 156775-Bureau of the Census 2001, p. 33). In 1995, output (the value of goods and services produced in the five locations) ranged from $18 billion to $55 billion. The income (wages, salaries, and property income) ranged from $9 billion to $26 billion, area employment ranged from 245,000 to 670,000 workers in 1995, and plant employment ranged from 25 to 995 (DIRS 101941-USN 1996, p. 4-6). Based on averages of this information, the representative manufacturing location has a population of about 690,000 and the representative plant employs 480. Local output in the area is $30 billion, local income is $15 billion, and local employment is 390,000.

4.1.15.5 Environmental Impacts

As mentioned in Section 4.1.15.4, this evaluation considered only existing manufacturing facilities, so environmental impact analyses are limited to air quality, health and safety, waste generation, and socioeconomics. Impacts are presented for the higher-temperature operating mode and a range of impacts are presented for the lower-temperature operating mode. In addition, this section contains a discussion of environmental justice.

4.1.15.5.1 *Air Quality*

The analysis used the baseline data and methods developed in DIRS 101941-USN (1996, Section 4.3) to estimate air emissions from manufacturing sites for the production of repository components. Criteria pollutants and hazardous air pollutants were considered, and predicted emissions were compared with typical regional or county-wide emissions to determine potential impacts of the emissions on local air quality.

Potential emissions were evaluated for a representative manufacturing location using the ambient air quality characteristics of typical manufacturing facilities, as described in Section 4.1.15.4. The analysis assumed that the representative location used for this analysis would be in a nonattainment area for ozone and in attainment areas for carbon monoxide and particulate matter. Therefore, ozone was the only criteria pollutant analyzed. Ozone is not normally released directly to the atmosphere, but is produced in a complex reaction of precursor chemicals (volatile organic compounds and nitrous oxides) and sunlight. This section evaluates the emissions of these precursors.

The reference air emissions associated with the manufacture of repository components were developed using the emissions resulting from manufacturing similar components (DIRS 101941-USN 1996, p. 4-6) and were normalized based on the number of work hours required for the manufacturing process. The analysis prorated these reference emissions on a per-unit basis to calculate annual emissions at the reference manufacturing site, assuming emissions from similar activities would be proportional to the number of work hours in the manufacturing process. To provide reasonable estimates of emissions, the analysis assumed that the volatile organic compounds used as cleaning fluids would evaporate fully into the atmosphere as a result of the cleaning processes used in manufacturing. The estimates of emissions were based on the total number of repository components manufactured over a 10-year period for drip shields and a 24-year period for all other components.

Table 4-46 lists the estimated annual average and estimated total emissions from the manufacture of components at the representative facility for each packaging scenario. Estimated annual average emissions of volatile organic compounds would vary from 1.0 to 1.5 metric tons (approximately 1.1 to 1.5 tons) a year for the 24-year period and from 0.59 to 0.89 metric ton (approximately 0.60 to 0.91 ton) for the 10-year drip shield manufacturing period. Nitrous oxide emissions vary from 1.3 to 1.9 metric tons (approximately 1.4 to 1.8 tons) a year for the 24-year period and from 0.76 to 1.2 metric tons (approximately 0.79 to 1.2 tons) for the 10-year drip shield manufacturing period. Annual average emissions from component manufacturing under any of the scenarios would be less than 0.05 percent of

Table 4-46. Ozone-related air emissions (metric tons)[a] at the representative manufacturing location.

		Operating mode/packaging scenario[b]		
		UC	DPC	UC/DPC/DISP
Compound	Measure	HT	HT	LT[c]
Volatile organic compounds				
24-year period[d]	Annual average	1.0	1.0	1.0 - 1.5
	24-year total	25	26	25 - 35
	Percent of *de minimis*[e]	11	12	11 - 16
10-year period[f]	Annual average	0.59	0.59	0.65 - 0.89
	10-year total	5.9	5.9	6.5 - 8.9
	Percent of *de minimis*	6.5	6.5	7.1 - 9.8
Nitrogen oxides				
24-year period	Annual average	1.3	1.4	1.3 - 1.9
	24-year total	32	33	32 - 46
	Percent of *de minimis*	15	15	15 - 21
10-year period	Annual average	0.76	0.76	0.85 - 1.2
	10-year total	7.6	7.6	8.5 - 12
	Percent of *de minimis*	8.4	8.4	9.3 - 13

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = *dual-purpose canister*; HT = higher-temperature operating mode; LT = lower-temperature operating mode.
c. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the DISP packaging scenario.
d. The 24-year manufacturing period is for all components except drip shields and begins 2 years prior to emplacement.
e. *De minimis* level for an air quality region in extreme nonattainment for ozone is 9.1 metric tons per year of volatile organic compounds or nitrogen oxides (40 CFR 51.853).
f. The 10-year manufacturing period is for drip shields only and occurs at repository closure.

regional emissions of volatile organic compounds and 0.005 percent of regional emissions of nitrous oxides. Emissions from the manufacture of repository components would contain a relatively small amount of ozone precursors compared to other sources.

The examination assumed that the emissions of volatile organic compounds and nitrous oxides were new sources; these emissions were compared with emission threshold levels (emission levels below which conformity regulations do not apply). There are different categories of ozone nonattainment areas based on the sources of ozone and amount of air pollution in the region. The different categories have different emission threshold levels (40 CFR 51.853).

For an air quality region to be in extreme nonattainment for ozone (most restrictive levels), the emission threshold level for both volatile organic compounds and nitrous oxides is 9.1 metric tons (10 tons) per year. Table 4-46 also lists the percentage of volatile organic compounds and nitrous oxides from the manufacture of repository components in relation to the emission threshold level of an extreme ozone nonattainment area. Annual air emissions from the manufacture of repository components would vary depending on the operating mode and packaging scenario, with ranges of 6.5 to 16 percent and 8.4 to 21 percent of the emission threshold levels for volatile organic compounds and nitrous oxides, respectively. In all of the packaging scenarios, component manufacturing would not be likely to fall under the conformity regulations because the predicted emissions of volatile organic compounds and nitrous oxides would be well below (less than 21 percent of) the emission threshold level of 9.1 metric tons per year. However, DOE would ensure the implementation of the appropriate conformity determination processes and written documentation for each designated manufacturing facility.

States with nonattainment areas for ozone could place requirements on many stationary pollution sources to achieve attainment in the future. This could include a variety of controls on emissions of volatile organic compounds and nitrous oxides. Various options such as additional scrubbers, afterburners, or carbon filters would be available to control emissions of these compounds to comply with limitations.

4.1.15.5.2 *Health and Safety*

The analysis used data on the metal fabrication and welding industries from the Bureau of Labor Statistics to compile baseline occupational health and safety information for industries that fabricate steel and steel objects similar to the repository components (DIRS 101941-USN 1996, p. 4-8). The expected number of injuries and fatalities were computed by multiplying the number of work years by the injury and fatality rate for each occupation.

Table 4-47 lists the expected number of injuries and illnesses and fatalities for each scenario based on the work years required to produce the number of components. Injuries and illnesses would range from 580 to 840, depending on the operating mode and packaging scenario. Fatalities would be unlikely.

Table 4-47. Occupational injuries, illness, and fatalities at the representative manufacturing location.[a]

	Operating mode/packaging scenario		
	Higher-temperature		Lower-temperature[b]
Parameter	UC	DPC	UC/DPC/DISP[c]
Injuries and illnesses	580	600	600 - 840
Fatalities	0.28	0.28	0.28 - 0.40

a. Impacts from 24 years for manufacture for all components except drip shields and 10 years for manufacture of drip shields.
b. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the DISP packaging scenario.
c. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.

The required number of repository components would not place unusual demands on existing manufacturing facilities. Thus, none of the scenarios would be likely to lead to a deterioration of worker safety and a resultant increase in accidents. In addition, nuclear-grade components are typically built to higher standards and with methods that are more proceduralized, both of which lead to improved worker safety.

4.1.15.5.3 *Socioeconomics*

The assessment of socioeconomic impacts from manufacturing activities involved three elements:

- Per-unit cost data for disposal containers, emplacement pallets, and drip shields (DIRS 150558-CRWMS M&O 2000, all) and per-unit cost of shipping casks (DIRS 104967-CRWMS M&O 1998, Table 12, pp. 17 and 18)
- Total number of components
- Economic data for the environmental setting for each facility to calculate the direct and secondary economic impacts of repository component manufacturing on the local economy (DIRS 103074-BEA 1992, all)
  - The local economy would be directly affected as manufacturing facilities purchased materials, services, and labor required for manufacturing.
  - The local economy would also experience secondary effects as industries and households supplying the industries that were directly affected adjusted their own production and spending behavior in response to increased production and income, thereby generating additional socioeconomic impacts.

Impacts were measured in terms of output (the value of goods and services produced), income (wages, salaries, and property income), and employment (number of jobs).

The socioeconomic analysis of manufacturing used state-level economic multipliers for fabricated metal products (DIRS 103074-BEA 1992, all). To perform the analysis, DOE obtained the product, income, and employment multipliers for the states where the five existing manufacturing facilities are located. (Multipliers account for the secondary effects on an area's economy in addition to providing direct effects on its economy). The multipliers were averaged to produce composite multipliers for a representative manufacturing location. The composite multipliers were used to analyze the impacts of each alternative. Table 4-48 lists the state-specific multipliers and the composite multipliers.

Table 4-48. Economic multipliers for fabricated metal products.[a]

State	Final demand multiplier ($)		Direct effect multiplier (number of jobs)
	Products	Earnings	
Massachusetts	1.8927	0.5555	2.2050
North Carolina	1.9145	0.5426	2.1544
Ohio	2.6019	0.7260	3.1064
Pennsylvania	2.5697	0.7194	2.8552
Tennessee	2.1379	0.6107	2.5314
Composite	2.2233	0.6308	2.5705

a. Source: DIRS 103158-Bureau of the Census (1992, all).

The analysis was limited to estimating the direct and secondary impacts of manufacturing activities. No assessment was made of the impacts of manufacturing activities on local jurisdictions. Such an analysis would include the estimation of impacts on county and municipal government and school district revenues and expenditures. Because the production of repository components probably would occur at existing facilities alongside existing product lines, a substantial population increase due to workers moving into the vicinity of the manufacturing sites in a given year under any scenario would be unlikely. Due to this lack of demographic impacts, meaningful change in the disposition of local government or school district revenues and expenditures would be unlikely. Because substantial population increases would not be likely, the analysis did not consider impacts on other areas of socioeconomic concern, such as housing and public services.

The analysis calculated average annual impacts for the manufacturing period of 10 years for drip shields and 24 years for all other components. The impacts of each packaging scenario were compared to the baseline at the representative location in 1995, with results expressed in millions of 2001 dollars. No attempt was made to forecast local economic growth or inflation rates for each representative location because of the non-site-specific nature of the analysis.

Table 4-49 lists the impacts of each operating mode and packaging scenario on output, income, and employment at the representative manufacturing location. The impacts include the percent of each scenario in relation to overall output, income, and employment in the economy.

Local Output

The average annual output impacts of each scenario would range from about $620 million to about $1,200 million (Table 4-48) depending on the operating mode and packaging scenario. Output generated from each scenario would increase total local output from between 1.8 percent and 2.4 percent, on average, over the 24-year manufacturing period, and from between 2.4 percent and 3.5 percent over the 10-year drip shield manufacturing period.

Table 4-49. Socioeconomic impacts for operating modes and packaging scenarios at the representative manufacturing location.

Flexible design/ packaging scenario[a]	Average annual output[b] $ (millions)	Average annual output[b] Percent impact[c]	Average annual income $ (millions)	Average annual income Percent impact	Average annual employment Person-years	Average annual employment Percent impact
UC						
HT 24-year period[d]	620	1.8	180	1.1	800	0.21
HT 10-year period[e]	810	2.4	230	1.4	460	0.12
DPC						
HT 24-year period	630	1.8	180	1.1	820	0.21
HT 10-year period	810	2.4	230	1.4	460	0.12
UC/DPC/DISP[f]						
LT 24-year period	620 - 790	1.8 - 2.3	180 - 220	1.1 - 1.3	800 - 1,100	0.21 - 0.29
LT 10-year period	1,000 - 1,200	2.9 - 3.5	290 - 350	1.7 - 2.1	510 - 690	0.13 - 0.18

a. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister; HT = higher-temperature operating mode; LT = lower-temperature operating mode.
b. Annual output and income impacts are expressed as millions of 2001 dollars.
c. Percent impact refers to the percentage of the baseline data discussed in Section 4.1.15.4 for the representative site, escalated to 2001 dollars.
d. The 24-year manufacturing period is for all components except drip shields and begins two years prior to emplacement.
e. The 10-year manufacturing period is for drip shields only and occurs at repository closure.
f. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the DISP packaging scenario.

Local Income

The average annual income impacts of each packaging scenario would range from about $180 million to about $350 million (Table 4-48) depending on the operating mode and packaging scenario. Income generated from each scenario would increase total local income between 1.1 percent and 1.3 percent over the 24-year manufacturing period and from between 1.4 percent and 2.1 percent over the 10-year drip shield manufacturing period.

Local Employment

The average annual employment impacts of each packaging scenario would range from about 460 to about 1,100 work years (Table 4-48), depending on the operating mode and packaging scenario. Employment generated from any of the scenarios would increase total local employment about 0.22 percent, on average, over the 24-year manufacturing period and about 0.14 percent, on average, over the 10-year drip shield manufacturing period.

4.1.15.5.4 *Impacts on Material Use*

To the extent available, DOE based the calculations of the quantities of materials it would use for the manufacture of each component on engineering specifications for each hardware component. This information was provided by the manufacturers of systems either designed or under licensing review (DIRS 101941-USN 1996, Sections 3.0 and 4.1.1; DIRS 150558-CRWMS M&O 2000, all; DIRS 102030-CRWMS M&O 1999, all), or from conceptual design specifications for technologies still in the planning stages (DIRS 101837-JAI 1996, all). Data on per-unit material quantities for each component were combined with information on the number of components to be manufactured for each operating mode and packaging scenario. In addition, the analysis assessed the impact of component manufacturing for each scenario on the total U.S. production (or availability in the United States, if not produced in this country) of each relevant input material. The results of the assessment are expressed in terms of percent impacts on total U.S. domestic production of most commodities.

Table 4-50 lists estimated total quantities of materials that DOE would need for each packaging scenario along with the annual average requirement for each material. For each scenario the largest material

Table 4-50. Material use (metric tons).[a]

Material	Basic material use per operating mode/packaging scenario[b]					
	Higher-temperature				Lower-temperature	
	UC		DPC		UC/DPC/DISP[c]	
	Total	Annual	Total	Annual	Total	Annual
Aluminum	2,600	110	2,600	110	90 - 2,600	4 - 110
Chromium[d]	52,000	2,200	52,000	2,200	52,000 - 63,000	2,200 - 2,600
Copper	36	1	73	3	36 - 140	1 - 6
Depleted uranium	880	37	88	4	88-1,400	4 - 60
Lead	430	18	3,300	140	430 - 3,300	18 - 140
Molybdenum[e]	14,000	600	14,000	600	14,000 - 17,000	600 - 700
Nickel[f]	82,000	3,400	83,000	3,500	83,000 - 100,000	3,500 - 4,200
Steel[g]	150,000	6,300	150,000	6,300	150,000 - 330,000	6,300 - 14,000
Titanium	43,000	4,300	43,000	4,300	54,000 - 65,000	5,400 - 6,500

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the disposable canister packaging scenario.
d. Chromium estimated as 18 percent of stainless steel and 22 percent of nickel base alloy.
e. Molybdenum estimated as 13.5 percent of nickel base alloy.
f. Nickel estimated as 58 percent of nickel base alloy and 14 percent of stainless steel.
g. Steel estimated as 100 percent of carbon steel and 52 percent of stainless steel.

requirement by weight would be steel, ranging from about 150,000 to about 330,000 metric tons (160,000 to 360,000 tons), depending on the operating mode and packaging scenario.

Table 4-51 compares the annual U.S. production capacity to the annual requirements for the materials each scenario would use. With the exception of chromium, nickel, and titanium, consumption for each scenario would be less than 1.5 percent of the annual U.S. production.

Table 4-51. Annual amount (metric tons)[a] of material required for manufacturing, expressed as a percent of annual U.S. domestic production.

Material	Production[d,e,f]	Basic material use per flexible design operating mode/packaging scenario[b]					
		Higher-temperature				Lower-temperature	
		UC		DPC		UC/DPC/DISP[c]	
		Annual	Percent	Annual	Percent	Annual (max)[g]	Percent
Aluminum	5,000,000	110	0.002	110	0.002	110	0.002
Chromium	104,000	2,200	2.1	2,200	2.1	2,600	2.5
Copper	1,900,000	1	0.0001	3	0.0002	6	0.0003
Depleted uranium	14,700	37	0.25	4	0.03	60	0.41
Lead	430,000	18	0.004	140	0.03	140	0.03
Molybdenum	57,000	600	1.05	600	1.1	700	1.2
Nickel	14,600	3,400	23	3,500	24	4,200	29
Steel	91,500,000	6,300	0.007	6,300	0.007	14,000	0.01
Titanium	22,000	4,300	20	4,300	20	6,500	30

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister; HT = higher-temperature operating mode; LT = lower-temperature operating mode.
c. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the disposable canister packaging scenario.
d. Source: DIRS 103156-Bureau of the Census (1997, Table 1155, p. 700, and Table 1244, p. 756).
e. Source for depleted uranium production: DIRS 101941-USN (1996, p. 4-10).
f. Source for titanium production: DIRS 152457-Gambogi (1999, Volume 1, Table 2, p. 80.7).
g. Maximum from range for lower-temperature operating modes is reported here.

Therefore, the use of aluminum, copper, lead, molybdenum, depleted uranium or steel would not produce a noteworthy increased demand and should not have a meaningful effect on the supply of these materials.

The annual requirement for chromium as a component in stainless-steel and high-nickel alloy ranges from about 2.12 percent to about 2.5 percent of the annual U.S. production, depending on the flexible design operating mode and packaging scenario. Most chromium, which is an important constituent of many types of stainless steel, is imported into the United States and is classified as a Federal Strategic and Critical Inventory material. For comparative purposes, the maximum total requirement of about 63,000 metric tons (65,000 tons) can be evaluated as a percentage of the 1994 strategic chromium inventory of 1.04 million metric tons (1.15 million tons) (DIRS 103156-Bureau of the Census 1997, Table 1159, p. 702). The total repository program need would be about 6 percent of the strategic inventory. With the strategic inventory to support the program demand, chromium use should not cause any market or supply impacts.

Annual nickel use as a component in stainless steel and corrosion-resistant high-nickel alloys appears, relatively, the most important in comparison to U.S. production. The magnitude of the comparison is the result of low U.S. production because the United States imports most of the nickel it uses. Although the annual U.S. production of nickel is only 14,600 metric tons (16,100 tons), the annual U.S. consumption is 158,000 metric tons (174,000 tons) (DIRS 103156-Bureau of the Census 1997, Table 1155, p. 700). This annual consumption is supported by a robust world production of 1.04 million metric tons (1.15 million tons) (DIRS 103156-Bureau of the Census 1997, Table 1158, p. 702). The maximum annual program need is a little less than 3 percent of the U.S. consumption and about 0.5 percent of world production. Canada is a major world supplier of nickel. DOE does not anticipate that the maximum program demand would affect the U.S. or world nickel markets.

The annual amount of depleted uranium used over 24 years would range from 0.25 percent to 0.41 percent of the total U.S. annual production. These requirements would be small. Given the limited alternative uses of this material and the large current inventory of surplus depleted uranium hexafluoride owned by DOE, such impacts should be considered to be positive (DIRS 101941-USN 1996, p. 4-10). Lead or steel could be substituted for depleted uranium for radiation shielding in some cases. If those materials were used for this purpose, the thickness of the substituted material would increase in inverse proportion to the ratio of the density of the substituted material to the density of depleted uranium. If lead or steel were used, the shielding thickness would increase by about 170 percent or 240 percent, respectively, resulting in a much larger container (DIRS 101941-USN 1996, p. 4-10).

The annual requirement for titanium for drip shields ranges from about 4,300 to 6,500 metric tons (4,740 to 7,165 tons), depending on the operating mode and packaging scenario. The magnitude of the comparison is the result of low U.S. production of the basic raw material, because the United States imports most of the titanium raw material. Although the annual U.S. production of titanium raw material is only 21,600 metric tons (23,810 tons), the annual U.S. capacity to produce titanium ingots is 78,200 metric tons (86,200 tons) (DIRS 152457-Gambogi 1999, p. 80.7). The maximum annual program need is a little over 8 percent of the current annual U.S. ingot production. Titanium is classified as a Federal Strategic and Critical Inventory material and is the ninth most common element in the Earth's crust (DIRS 107031-U.S. Bureau of Mines 1985, p. 859). Because the drip shields would not be needed until repository closure, there would be adequate time (over 100 years) to complete production of titanium raw material or to import additional raw material in advance of the need to reduce impact on markets.

4.1.15.5.5 *Impacts of Waste Generation*

The component materials used in the manufacture of repository components would be carbon steel, high-nickel alloy, stainless steel, aluminum, copper, and titanium with either depleted uranium or lead used for shielding. The manufacture of shielding would generate hazardous or low-level radioactive waste, depending on the material used. Other organic and inorganic chemical wastes generated by the manufacture of repository components and the amounts generated have also been identified.

Based on data in DIRS 101941-USN (1996, p. 4-13), the analysis estimated annual volumes and quantities of waste produced for each scenario per component manufactured at the representative site. The potential for impacts was evaluated in terms of existing and projected waste handling and disposal procedures and regulations. In addition to relevant state regulatory agencies, the Environmental Protection Agency and the Occupational Safety and Health Administration regulate the manufacturing facilities.

Manufacturing to support the different flexible design operating modes and packaging scenarios would produce liquid and solid wastes at the manufacturing locations. To control the volume and toxicity of these wastes, manufacturers would comply with existing regulations. Pollution prevention and reduction practices would be implemented. The analysis evaluated only waste created as a result of the manufacturing process to produce repository components from component materials. It did not consider the waste produced in mining, refining, and processing raw materials into component materials for distribution to the manufacturer. The analysis assumed that the component materials, or equivalent component materials produced from the same raw materials, would be available from supplier stock, which would be available without regard to the status of the Yucca Mountain project.

Liquid Waste

The liquid waste produced during manufacturing would consist of used lubricating and cutting oils from machining operations and the cooling of cutting equipment. This material is currently recycled for reuse. Ultrasonic weld testing would generate some unpotable water-containing glycerin. Water used for cooling and washing operations would be treated for release by filtration and *ion* exchange, which would remove contaminants and permit discharge of the treated water to the sanitary system.

Table 4-52 lists the estimated amounts of liquid waste generated by the shaping, machining, and welding of the components required for each scenario. The annual average amount of liquid waste generated would range from 4.1 to 6.4 metric tons (approximately 4.2 to 6.5 tons) per year during either the 24-year or 10-year manufacturing periods. The small quantities of waste produced during manufacturing would not exceed the capacities of the existing equipment for waste stream treatment at the manufacturing facility.

Table 4-52. Annual average waste generated (metric tons)[a] at the representative manufacturing location.

		Operating mode/packaging scenario[b]		
		Higher-temperature		Lower-temperature
Compound	Measure	UC	DPC	UC/DPC/DISP[c]
Liquid				
24-year period[d]	Annual average	4.3	4.3	4.3 - 6.4
10-year period[e]	Annual average	4.1	4.1	4.4 - 6.2
Solid				
24-year period[d]	Annual average	0.59	0.59	0.59 - 0.88
10-year period[e]	Annual average	0.57	0.57	0.61 - 0.86

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the DISP packaging scenario.
d. The 24-year manufacturing period is for all components except drip shields and begins two years prior to emplacement.
e. The 10-year manufacturing period is for drip shields only and occurs at repository closure.

Main Index Vol 1 Index

Solid Waste

Table 4-52 lists the solid waste that manufacturing operations would generate. The annual average amount of solid waste would range from 0.57 to 0.88 metric ton (approximately 0.58 to 0.90 ton) per year during either the 24-year or the 10-year manufacturing periods. The primary waste constituents would be steel and components of steel including nickel, manganese, molybdenum, chromium, and copper. These chemicals could be added to existing steel product manufacturing waste streams for treatment and disposal or recycling.

The analysis assumed that depleted uranium to be incorporated in the components would be delivered to the manufacturing facility properly shaped to fit as shielding for a shipping cask. As a result, depleted uranium waste would not be generated or recycled at the representative manufacturing site and would not pose a threat to worker health and safety. Lead used for gamma shielding would be cast between stainless-steel components for the shipping casks. Although the production of a substantial quantity of lead waste under any of the packaging scenarios would be unlikely, such waste would be recycled.

4.1.15.5.6 *Environmental Justice*

The purpose of this environmental justice assessment is to determine if disproportionately high and adverse health or environmental impacts associated with the manufacture of repository components would affect minority or low-income populations, as outlined in Executive Order 12898 and the President's accompanying cover memorandum. Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,* directs Federal agencies to identify and address disproportionately high and adverse human health or environmental effects of their programs and activities on minority and low-income populations. A disproportionately high impact would be an impact (or risk of an impact) in a minority or low-income community that exceeded the corresponding impact on the larger community to a meaningful degree. The analysis discussed below is the analysis used in DIRS 101941-USN (1996, Section 4.8), which was adapted to the manufacturing of components for the Yucca Mountain Repository.

The environmental justice assessment considered human health and environmental impacts from the examination of impacts on air quality, waste generation, and health and safety. The assessment used demographic data to provide information on the degree to which minority or low-income populations would be disproportionately affected. The evaluation identified as areas of concern those in which minority or low-income populations could suffer disproportionately high and adverse impacts.

This evaluation used a representative site based on five facilities that manufacture casks or canisters and related hardware for spent nuclear fuel.

To explore potential environmental justice concerns, this assessment examined the composition of populations living within approximately 16 kilometers (10 miles) of the five manufacturing facilities to identify the number of minority and low-income individuals in each area. The percentages of minority and low-income persons comprising the population of the states where the facilities are located were used as a reference. DOE selected this radius because it would capture the most broadly dispersed environmental consequences associated with the manufacturing activities, which would be impacts to air quality. The number of persons in each target group in the defined area was compared to the total population in the area to yield the proportion of minority and low-income persons within approximately 16 kilometers of each facility.

A geographic information system was used to define areas within approximately 16 kilometers (10 miles) of each facility. Linked to 1990 census data, this analytical tool enabled the identification of block groups within 16 kilometers. In cases where the 16-kilometer limit divided block groups, the system calculated the fraction of the total area of each group that was inside the prescribed distance. This fraction provided the basis for estimating the total population in the area as well as the minority and low-income components.

The analysis indicated that in one location the proportion of the minority population in the area associated with the manufacturing facility is higher than the proportion of the minority population in the state. The difference between the percentage of the minority population living inside the 16-kilometer (10-mile) radius and the state is 1.5 percent (DIRS 101941-USN 1996, p. 4-18). DOE anticipates very small impacts for the total population from manufacturing activities associated with all the scenarios, so there would be no disproportionately high and adverse impacts to the minority population near this facility.

In addition, the percentage of the total population that consists of low-income families living within about 16 kilometers (10 miles) of a manufacturing facility would exceed that of the associated state in one instance. The difference in this case was 0.9 percent (DIRS 101941-USN 1996, p. 4-18). DOE anticipates very small impacts to individuals and to the total population, and no special circumstances would cause disproportionately high and adverse impacts to the low-income population living near the facility.

The EIS analysis determined that only small human health and environmental impacts would occur from the manufacture of repository components. Disproportionately high and adverse impacts to minority or low-income populations similarly would be unlikely from these activities.

4.2 Short-Term Environmental Impacts from the Implementation of a Retrieval Contingency or Receipt Prior to the Start of Emplacement

4.2.1 IMPACTS FROM RETRIEVAL CONTINGENCY

Section 122 of the Nuclear Waste Policy Act requires DOE to maintain the ability to retrieve emplaced waste for an appropriate period after the start of emplacement. Nuclear Regulatory Commission regulations at 10 CFR 63.111(e) specify a retrieval period of at least 50 years. Because of this requirement, the EIS analyzed the impacts of retrieval. Although DOE does not anticipate retrieval and it is not part of the Proposed Action, DOE would maintain the ability to retrieve the waste for at least 100 years and possibly for as long as 324 years in the event of a decision to retrieve the waste either to protect the public health and safety or the environment or to recover resources from spent nuclear fuel. Some of the impacts that could occur during retrieval have been addressed in the Proposed Action under the lower-temperature operating mode with surface aging. This operating mode would include surface aging of up to two-thirds of the commercial spent nuclear fuel over a 50-year operations period (Chapter 2, Section 2.1.1.2.2). This aging facility could be used to store a portion of any spent nuclear fuel or high-level radioactive waste that would be retrieved.

This EIS evaluates retrieval as a contingency action and describes potential impacts if it were to occur. The analysis in this EIS assumes that under this contingency DOE would retrieve all the waste and would place it on a surface storage pad pending future decisions about its ultimate disposition. Storage of spent nuclear fuel and high-level radioactive waste on the surface would be in compliance with applicable regulations.

4.2.1.1 Retrieval Activities

If there was a decision to retrieve spent nuclear fuel and high-level radioactive waste from the repository, DOE would move the waste packages from the emplacement drifts to the surface. Operations in the subsurface facilities to remove the waste packages would be the reverse of emplacement operations and would use the same types of equipment (see Chapter 2, Section 2.1.2.2).

On the surface, the retrieved waste packages would be loaded on a vehicle for transport to a Waste Retrieval and Storage Area in Midway Valley, about 3.7 kilometers (2.3 miles) from the North Portal Operations Area, to which DOE would build a rail line or roadway. Figure 4-5 shows the relationship between these areas. The Waste Retrieval and Storage Area would include a Waste Retrieval Transfer Building, support facilities, and a number of concrete storage pads. To retrieve and store 70,000 MTHM of spent nuclear fuel and high-level radioactive waste, these facilities would cover about 1.5 square kilometers (380 acres) (DIRS 152010-CRWMS M&O 2000, Table I-2).

DOE based its selection of Midway Valley Wash as the site for retrieval activities on the following site selection criteria:

- Proximity to the repository North Portal Operations Area
- Retrieval of the waste in the shortest possible timeframe
- Adequate space for dry storage of 70,000 MTHM of waste
- No ground displacements due to earthquakes
- Siting outside the probable maximum flood zone
- Minimum costs for construction
- Minimum impacts to the environment

In the Waste Retrieval Transfer Building, the waste packages would be removed and placed in concrete storage modules (one container per module). The concrete module would protect the container and provide shielding. The module and container would then move to a concrete storage pad near the Waste Retrieval Transfer Building, where it would remain awaiting ultimate disposition. Figure 4-6 shows a concrete storage module design concept.

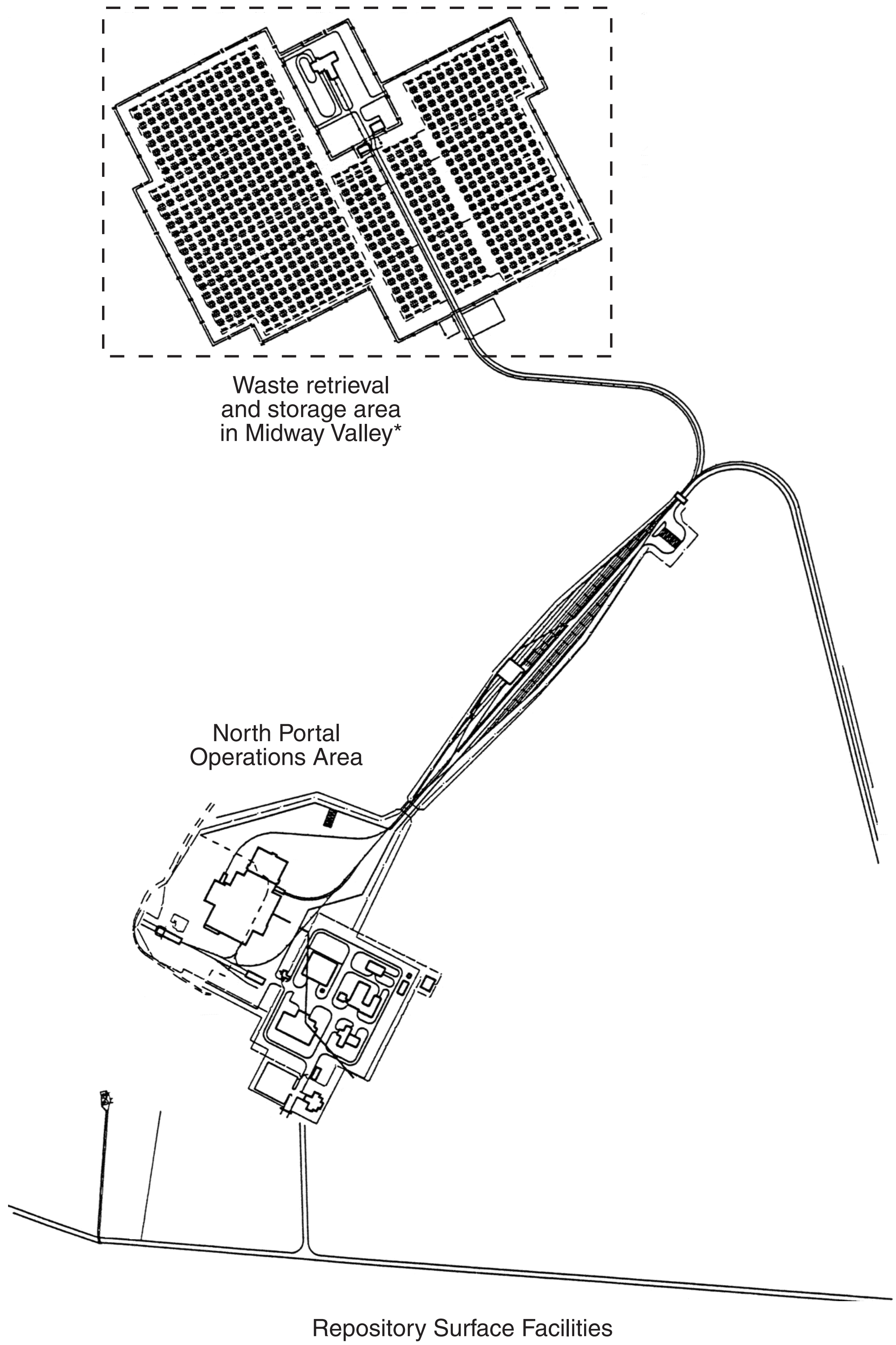
Studies of the strategies and options for retrieval (DIRS 100247-CRWMS M&O 1997, all) indicate that after a decision to retrieve the emplaced material, it would take about 10 years to plan the operation, procure the necessary equipment, and prepare the Waste Retrieval and Storage Area; subsequently, about 3 years would be needed for the initial construction of facilities and storage areas. After initial construction, the retrieval operations would require another 11 years, concurrent with an additional 7 years of storage area construction. DOE performed an impact analysis for the retrieval contingency only for the higher-temperature repository operating mode. Since 70,000 MTHM of spent nuclear fuel and high-level radioactive waste would be emplaced under the Proposed Action for all operating modes, the analysis of impacts for this operating mode is sufficient to describe the types and magnitudes of impacts that would occur if DOE implemented the retrieval contingency. Retrieval could be accomplished more quickly than the initial emplacement because limitations in material shipping and delivery as well as emplacement preparation (for example, waste package welding) would not be encountered.

4.2.1.2 Impacts of Retrieval

The following sections present the results of the environmental impact analysis for the retrieval contingency. They consider the construction of the Waste Retrieval and Storage Area, retrieval of the waste packages and their movement to the surface and to the Waste Retrieval and Storage Area, and the loading of the waste packages in concrete storage modules and their placement on concrete storage pads.

4.2.1.2.1 *Impacts to Land Use and Ownership from Retrieval*

Retrieval would cause no land use and ownership impacts during the construction of the Waste Retrieval and Storage area because the retrieval area would be on lands already withdrawn and under DOE control. DOE would develop the Waste Retrieval and Storage area on a 1.5-square-kilometer (380-acre) area approximately 3.7 kilometers (2.3 miles) north of the North Portal Operations Area in Midway Valley (see Figure 4-5). If DOE used surface aging under the lower-temperature repository operating mode, the



*See Figure 3-12 for more specific location of Midway Valley.

Source: DIRS 104508-CRWMS M&O (1999, Attachment I, Figure I-1).

Figure 4-5. Location of the Waste Retrieval and Storage Area in relation to the North Portal Operations Area.

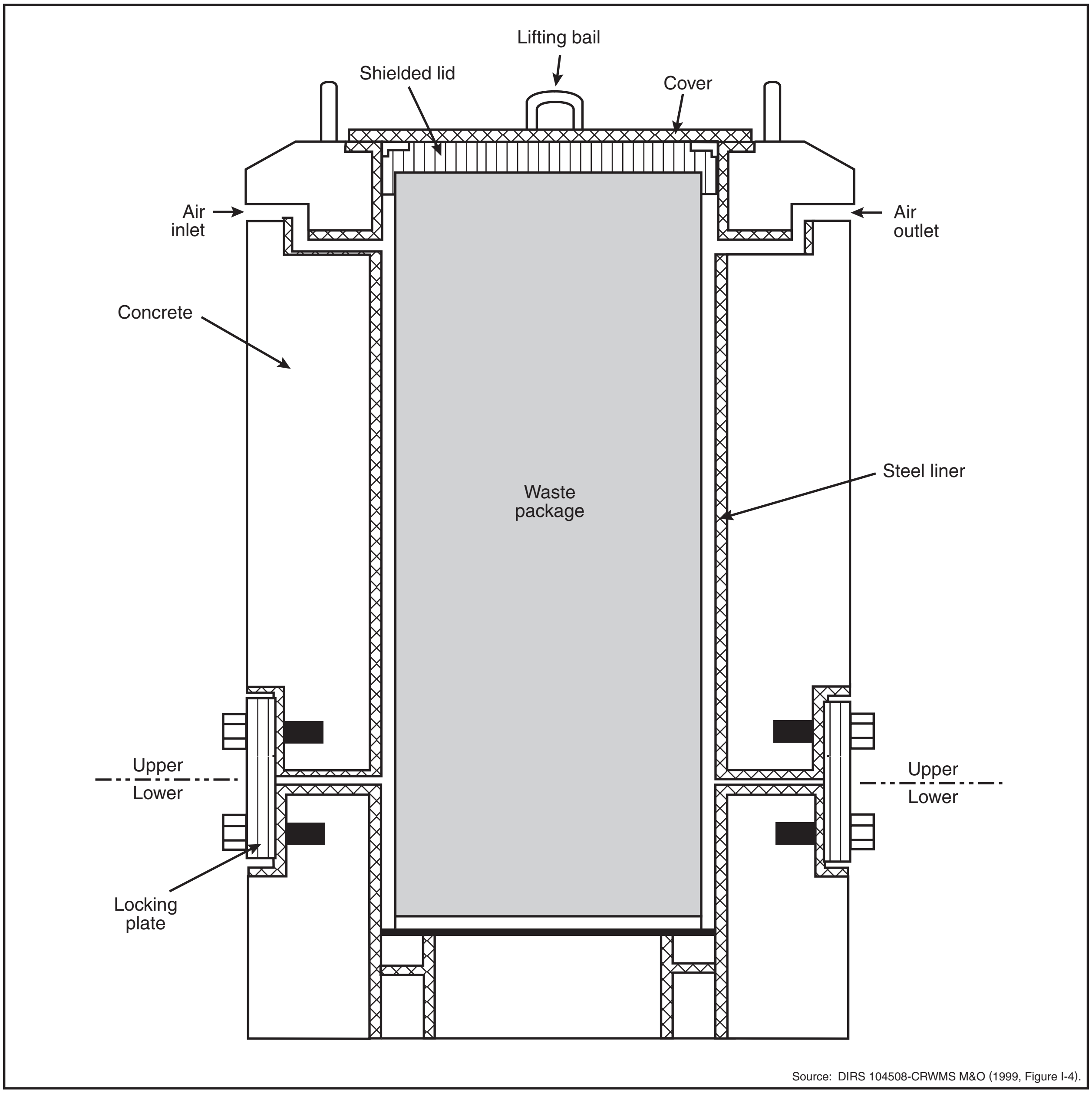


Figure 4-6. Typical concrete storage module design, vertical view.

aging pads could be available for use during retrieval operations, reducing the additional area disturbed for retrieval.

4.2.1.2.2 *Impacts to Air Quality from Retrieval*

The construction of the Waste Retrieval and Storage Area and the movement of the spent nuclear fuel and high-level radioactive waste to the surface would result in air quality impacts. The analysis considered both radiological and nonradiological impacts. No radiological air quality impacts would occur during the placement of the storage containers in concrete storage modules, assuming the containers remained intact and free from leaks during handling. However, radon-222 would be released from the active ventilation of the subsurface.

Nonradiological Air Quality Impacts. DOE evaluated nonradiological air quality impacts from the retrieval of materials from the repository for (1) the construction of a Waste Retrieval and Storage Area and (2) the retrieval process. Construction and retrieval activities would result in releases of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10}. Retrieval activities would not involve subsurface excavation or result in disturbance of the excavated rock pile, so no releases of cristobalite would occur.

Construction equipment would release nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} from fuel consumption. Fugitive dust, assumed to be all PM_{10}, would also be released during construction from earthmoving activities and operation of a concrete batch plant in the North Portal Operations Area. The analysis did not take credit for the standard construction dust suppression measures that DOE would implement to lower the projected PM_{10} concentrations. Table 4-53 lists calculated concentrations for criteria pollutant impacts at the location of the public maximally exposed individual and compares these concentrations to regulatory limits. The nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} concentrations at the location of the maximally exposed individual would be less than 2 percent of the applicable regulatory limits in all cases.

Table 4-53. Criteria pollutant impacts to public maximally exposed individual from retrieval (micro-grams per cubic meter).[a,b]

Pollutant	Averaging time	Regulatory limit[c]	Maximum concentration[d]	Percent of regulatory limit
Nitrogen dioxide	Annual	100	0.023	0.023
Sulfur dioxide	Annual	80	0.0022	0.0028
	24-hour	365	0.018	0.0049
	3-hour	1,300	0.14	0.011
Carbon monoxide	8-hour	10,000	0.20	0.0020
	1-hour	40,000	1.3	0.0033
Particulates (PM_{10}) ($PM_{2.5}$)	Annual	50 (15)	0.23	0.45
	24-hour	150 (65)	2.8	1.9

a. Appendix G, Section G.1, contains detailed information on the radiological air quality analysis.
b. All numbers except regulatory limits are rounded to two significant figures.
c. Regulatory limits from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Chapter 3, Table 3-5).
d. Sum of the highest concentrations at the accessible site boundary regardless of direction.

Radiological Air Quality Impacts. During retrieval activities subsurface ventilation would continue, resulting in releases of naturally occurring radon-222 and its decay products in the ventilation exhaust. Subsurface ventilation would continue for the duration of retrieval, lasting about 14 years with 3 years of initial construction (10 total years of construction), followed by 11 years of retrieval operations. Table 4-54 lists estimated annual and total doses from 14 years of retrieval activities to maximally exposed individuals and potentially affected populations from radon-222 released from subsurface facilities.

4.2.1.2.3 *Impacts to Hydrological Resources from Retrieval*

4.2.1.2.3.1 Surface Water. The retrieval activity that could have surface-water impacts would be the construction of the Waste Retrieval and Storage Area, which would disturb an area of 1.5 square kilometers (380 acres) (DIRS 152010-CRWMS M&O 2000, Table I-2).

Potential for Runoff Rate Changes. The total disturbed area would include areas cleared to support construction equipment and materials, facilities, and concrete storage pads. If DOE retrieved all the waste, the storage pad area would account for about 0.48 square kilometer (120 acres) of the disturbed land (DIRS 152010-CRWMS M&O 2000, Table I-1, p. I-12). Including the areas covered by facilities, roadways, and queuing areas, about half of the land disturbance would result in surface areas that would provide almost no infiltration, so precipitation would result in runoff from the Waste Retrieval and

Table 4-54. Estimated radiation doses to maximally exposed individuals and populations from subsurface radon-222 releases during the retrieval period.[a,b]

Impact	Total	Annual
Dose to public		
Maximally exposed individual[c] (millirem)	2.7	0.19
80-kilometer[d] population[e] (person-rem)	50	3.6
Dose to noninvolved (surface) workers		
Maximally exposed noninvolved (surface) worker[f] (millirem)	0.019	0.0040
Yucca Mountain noninvolved worker population (person-rem)	0.0045	0.00039
Nevada Test Site noninvolved worker population[g] (person-rem)	0.0031	0.00033

a. Appendix G, Section G.2, contains detailed information about the radiological air quality analysis.
b. Construction and retrieval activities would last 14 years.
c. At the southern boundary of the land withdrawal area.
d. 80 kilometers = 50 miles.
e. Approximately 76,000 individuals within 80 kilometers of the repository (see Chapter 3, Section 3.1.8).
f. Maximally exposed noninvolved worker would be at the South Portal Development Area.
g. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

Storage Area. As described in Section 4.1.3.2, if precipitation did not generate runoff from surrounding areas, the runoff from the storage area could travel to otherwise empty drainage channels, but would not go far. If precipitation generated runoff everywhere, there would be little difference in the quantity produced in the storage area; it just would occur earlier in the storm. In addition, a comparison of the 1.5 square kilometers (380 acres) of disturbed land to the estimated 12 square kilometers (3,000 acres) that make up the Midway Valley Wash drainage area (DIRS 108883-Bullard 1992, Table 5) indicates that changes in runoff and infiltration rates should have little impact on how the entire drainage area responded to precipitation events.

Potential for Altering Natural Drainage. The proposed location for the Waste Retrieval and Storage Area does not cross or intercept well-defined drainage channels with the exception of the northwest corner, which could be close to, or possibly overlay, a short stretch of the upper Midway Valley Wash. Other portions of the facility would be in an area where simple overland flow probably would dominate runoff events. Design layouts of the proposed facility call for the construction of an interceptor trench along the upstream (north) side of the area, extending down either side; this would prevent runoff from entering the storage facility and could be an alteration to existing drainage. If flow in this short stretch of the upper Midway Valley Wash was intercepted, it would be diverted around the facility and then back to the existing course. Siting criteria for this proposed facility state that it will be located in a manner to minimize the engineering needed to protect it against the probable maximum flood zone (DIRS 152010-CRWMS M&O 2000, p. I-5). Therefore, a probable maximum flood in this small wash would not affect the retrieved material.

Potential for Flooding. The Waste Retrieval and Storage Area would be outside the probable maximum flood zone, although natural drainage might be altered to ensure this is the case. The interceptor trench on the north side of the facility would accommodate the highest quantities of runoff that could reasonably be present. Therefore, there would be no reasonable potential for flooding to affect the storage facility.

4.2.1.2.3.2 Groundwater. The retrieval activities that could have impacts on groundwater would be the construction of the Waste Retrieval and Storage Area and the retrieval of the emplaced material.

Potential for Infiltration Rate Changes. About half of the disturbed land would be covered by facilities, roadways, queuing areas, and storage pads. These facilities would be relatively impermeable to water, and would cause an additional amount of runoff to drainage channels in comparison to natural conditions. This additional runoff could cause a net increase in the amount of water to infiltrate these natural channels. The additional infiltration would move into the unsaturated zone and represent potential recharge to the aquifer, but it would be a minor amount in comparison to natural infiltration.

Impacts to Groundwater Resources. The estimated annual groundwater demand during retrieval would peak at about 170,000 cubic meters (140 acre-feet) a year (DIRS 152010-CRWMS M&O 2000, pp. I-18 and I-20; DIRS 150941-CRWMS M&O 2000, p. 6-20). No adverse impacts would be likely from this demand, which would be well within historic use rates.

4.2.1.2.4 *Impacts to Biological Resources and Soils*

The retrieval activity that could affect biological resources and soils would be the construction of the Waste Retrieval and Storage Area.

4.2.1.2.4.1 Impacts to Biological Resources from Retrieval. Impacts to biological resources would be similar to those described for construction and operations (see Section 4.1.4).

Impacts to Vegetation. The construction of retrieval facilities would disturb vegetation in an area that is presently undisturbed. The predominant land cover types in Midway Valley are blackbrush and Mojave mixed scrub, both of which are extensively distributed regionally and in the State of Nevada.

Impacts to Wildlife. Impacts to wildlife from the retrieval contingency would be similar to those described for the construction and operation of the repository. They would consist of limited habitat loss and the deaths of individuals of some species as a result of construction activities and vehicle traffic, and would be in addition to those associated with repository construction and operation.

Impacts to Special Status Species. Impacts to special status species from the retrieval contingency would be similar, and in addition to, those described for repository construction. They would consist of loss of a small portion of locally available habitat for the desert tortoise and the deaths of individual tortoises due to construction activities and vehicle traffic.

Impacts to Wetlands. No wetlands would be affected by activities associated with retrieval.

4.2.1.2.4.2 Impacts to Soils from Retrieval. Concrete pads, facilities, and roadways at the Waste Retrieval and Storage Area would eventually cover about half of the 1.5 square kilometers (380 acres) of disturbed land, but a sizable portion would remain as disturbed soil.

Soil Loss. Erosion concerns during the construction of the retrieval facilities would be the same as those described for the construction of the repository facilities (see Section 4.1.4.4). The types of soils encountered would be similar to, if not the same as, those encountered during the construction at the North Portal Operations Area and South Portal Development Area. As during other project activities, DOE would use dust suppression measures to reduce the disturbed land's erodibility.

After the construction of the retrieval facilities, much of the area would no longer be exposed to erosion forces because structures would cover the soil. However, the uncovered disturbed areas would be more susceptible to erosion than the surrounding natural areas. This would be the case until the disturbed land had time to reach equilibrium, including the reestablishment of vegetation. Erosion, if it occurred, probably would involve small amounts of soil from small areas. The amount of soil that could move downwind or downgradient should not present unusual concerns.

Recovery. DOE would reclaim disturbed lands when they were no longer needed for retrieval operations.

Main Index Vol 1 Index

4.2.1.2.5 *Impacts to Cultural Resources from Retrieval*

The activity that could affect cultural resources would be the construction of the Waste Retrieval and Storage Area. The following sections discuss archaeological and historic resources and Native American interests in relation to retrieval.

Archaeological and Historic Resources. The results of earlier archaeological fieldwork indicate that there are no National Register-eligible archaeological resources on land recommended for the Waste Retrieval and Storage Area or near the proposed rail or road construction. Therefore, construction activities associated with retrieval probably would not result in direct impacts to National Register-eligible archaeological resources. As during repository construction and operation, increased activities and numbers of workers could increase the potential for indirect impacts to archaeological sites near the construction work.

Native American Interests. A Waste Retrieval and Storage Area in Midway Valley would be 500 meters (1,600 feet) west of the Yucca Wash local use area and Alice Hill. As described in DIRS 102043-AIWS (1998, all), these areas have cultural importance to Native Americans. There could be some direct or indirect impacts to these areas, depending on the specific locations of Native American significance boundaries.

4.2.1.2.6 *Impacts to Socioeconomics from Retrieval*

Waste retrieval activities would increase the repository workforce above that for ongoing monitoring and maintenance activities. A maximum annual employment of about 600 workers (DIRS 152010-CRWMS M&O 2000, pp. I-18 and I-20; DIRS 150941-CRWMS M&O 2000, p. 6-20) would be required during retrieval operations and concurrent storage pad construction. Retrieval would last about 14 years. Employment during retrieval would be less than during other project phases and would be unlikely to generate meaningful changes to the region of influence’s employment or economic measures. Regional impacts from retrieval would be small.

4.2.1.2.7 *Occupational and Public Health and Safety Impacts from Retrieval*

The analysis of health and safety impacts to workers considered industrial safety hazards and radiological impacts from construction and retrieval operations, as discussed earlier in this section. During construction activities DOE would build (1) the surface facilities necessary to handle retrieved waste packages and enclose them in concrete storage units in preparation for their placement on concrete storage pads, and (2) the concrete storage pads (see Section 4.2.1.1). No radioactive materials would be involved in the construction activities, so health and safety impacts would be limited to those associated with industrial hazards in the workplace. DOE expects initial construction to last about 3 years, with construction of the concrete storage pads continuing concurrently with retrieval operations for an additional 7 years.

During retrieval operations DOE would retrieve the waste packages and move them to the Waste Retrieval Transfer Building. Surface facility workers would unload the waste package from the transfer vehicle and place it on a concrete base. The waste package would be enclosed in a concrete storage unit that, with the waste package inside, would be placed on the concrete storage pad. Retrieval operations would last about 11 years. The analysis estimated the health and safety impacts from both industrial hazards and from radiological hazards from operations for both surface and subsurface workers.

Radiological impacts to the public could occur during all 14 years of the retrieval period when radon-222 and its decay products would be released to the environment in the exhaust stream from the subsurface ventilation system. There would be no other source of radiation exposure to the public, and no differentiation between the construction and operations activities.

The methods used to estimate health and safety impacts to workers and the public were the same as those used to estimate such impacts for the Proposed Action (see Appendix F, Section F.2.1). Additional information pertinent to health and safety impact analysis for retrieval is contained in Appendix F, Section F.4.

Industrial Health and Safety Impacts

Industrial health and safety impacts occur only to workers. As noted above, the only health and safety impacts during retrieval construction activities would be those from industrial hazards during normal workplace activities. These impacts are shown in Table 4-55. Projected fatality would be about 0.05 and projected lost workday cases would be about 46.

Table 4-55. Health and safety impacts from industrial hazards from retrieval construction, operations, and overall impacts.[a,b]

Worker group and impact category	Construction[c]	Retrieval operations[d]	Overall impact[e]
Involved workers			
Total recordable cases	80	35	120
Lost workday cases	38	15	53
Fatalities	0.04	0.03	0.07
Noninvolved workers			
Total recordable cases	16	35	51
Lost workday cases	8	17	25
Fatalities	0.01	0.04	0.04
All workers (totals)[e]			
Total recordable cases	96	70	170
Lost workday cases	46	32	78
Fatalities	0.05	0.07	0.12

a. Numbers rounded to two significant figures.
b. Sources: Calculated using impact rates from Appendix F, Table F-71 and full-time equivalent work years from Table F-70.
c. Source: Appendix F, Table F-73.
d. Source: Appendix F, Tables F-74 and F-75.
e. Totals might differ from sums of values due to rounding.

Industrial health and safety impacts from retrieval operations are also shown in Table 4-55, as are the overall impacts. Total impacts would be small, with an estimated total of 0.12 fatality and 78 lost workday cases.

Radiological Health Impacts

Radiological health impacts may occur to both workers and members of the public. Table 4-56 lists radiological health impacts for both surface and subsurface workers for the retrieval contingency as well as the total radiological impact to all workers. Most of the radiation dose would be to subsurface workers during retrieval operations, and Appendix F contains additional details on estimates of radiation dose to subsurface workers. Impacts would be small, with the latent cancer fatality likelihood for the maximally exposed individual being about 0.002. The calculated latent cancer fatality incidence to workers for retrieval would be 0.06.

The only source of radiation exposure to members of the public during construction and retrieval operations would be from releases of radon-222 and its decay products through the subsurface ventilation system exhaust. Table 4-54 presents the estimated radiation doses to members of the public from these releases.

Table 4-56. Radiological health impacts to workers from retrieval operations.[a,b,c]

Worker group and impact category	Surface facility workers	Subsurface facility workers	High/total[d]
Maximally Exposed Worker dose (rem)			*High*
Involved	0.28	5.9	5.9
Noninvolved	0	0.44	0.44
Probability of latent cancer fatality			
Involved	0.00011	0.002	0.002
Noninvolved	0	0.0002	0.0002
Worker population			*Total*
Collective dose (person-rem)			
Involved	8	120	130
Noninvolved	0	4	4
Total[e]	**8**	**130**	**140**
Number of latent cancer fatalities			
Involved	0.003	0.05	0.05
Noninvolved	0	0.002	0.002
Total[e]	**0.003**	**0.05**	**0.06**

a. Sources: Appendix F, Tables F-76 and F-77.
b. All impacts from operations. Radiological health impacts to workers during construction would be minimal.
c. Numbers are rounded to two significant figures.
d. Highest individual and population totals for the 11-year retrieval period.
e. Totals might differ from sums of values due to rounding.

Table 4-57 lists estimated radiological health impacts to the public for retrieval. The estimated radiological health impacts to members of the public from the retrieval contingency would be small. The likelihood of a latent cancer fatality for the maximally exposed individual would be about 0.0000013. The estimated latent cancer fatality incidence in the exposed population would be about 0.025.

Table 4-57. Radiological health impacts to the public for the retrieval period.

Worker group and impact category	Impact
Individual	
Maximally exposed individual dose (millirem)[a]	2.7
Latent cancer fatality probability	0.0000013
Population	
Collective dose (person-rem)[a]	50
Latent cancer fatality incidence	0.025

a. Source: Table 4-54.

4.2.1.2.8 *Impacts from Accidents During Retrieval*

During retrieval operations, activities at the repository would be essentially the reverse of waste package emplacement, except operations in the Waste Handling Building would not be necessary because the waste packages would not be opened. The handling accident scenario applicable for these operations would be bounded by the transporter runaway accident scenario evaluated in Section 4.1.8. The waste packages would be retrieved remotely from the emplacement drifts, transported to the surface, and transferred to a Waste Retrieval and Storage Area (DIRS 102702-CRWMS M&O 1997, all). This area would include a Waste Retrieval Transfer Building where the waste packages would be unloaded from the transporter, transferred to a vertical concrete storage unit, and moved to a concrete storage pad.

Because the retrieval operations would be essentially the same as the emplacement operations (in reverse), the accident scenarios involving the waste package during operations would bound the retrieval operation. The bounding accident scenario during emplacement would be a transporter runaway and derailment accident in a main drift (see Appendix H, Section H.2.1.4). For above-ground storage accidents, the accident analysis for the continued storage analysis would apply. Recent analyses have found that the only credible accident with the potential for radiological consequences would be an aircraft crash into one of the above-ground storage facilities. However, the aircraft would not penetrate the thickness of the waste package (DIRS 157108-Jason 2001, all).

The analysis assumed that above-ground storage following retrieval would be licensed in compliance with Nuclear Regulatory Commission requirements (10 CFR Part 72). These requirements specify that storage modules must be able to withstand credible accident-initiating events.

4.2.1.2.9 *Noise Impacts from Retrieval*

The analysis in Section 4.1.9 shows that there would be no appreciable noise impacts for the construction, operation and monitoring, and closure phases of repository operations. Noise impacts associated with retrieval would be less than those associated with repository operations because of the reduced scope of activities and the smaller number of workers required. Thus, noise impacts from retrieval operations would be small.

4.2.1.2.10 *Aesthetic Impacts from Retrieval*

Retrieval activities would not be likely to produce adverse impacts on the visual quality of the landscape surrounding Yucca Mountain. Retrieval would essentially be the reverse of emplacement and would use the same types of equipment. Impacts from emplacement would be small. The only difference from the emplacement activities would be the construction of a Waste Retrieval and Storage Area in Midway Valley north of the North Portal Operations Area with a connecting transportation corridor. These activities would occur in the repository area and in Class C scenic quality lands away from the public view and, therefore, would have no impact on the existing visual character of the landscape.

4.2.1.2.11 *Impacts to Utilities, Energy, Materials, and Site Services from Retrieval*

The following sections discuss utility, energy, materials, and site service impacts.

Utilities and Energy. The estimated electric power demand for retrieval would be less than 10 megawatts. This demand would be well within the capacity that would be available at the repository.

The fossil-fuel use estimated for retrieval activities would approach 25 million liters (6.6 million gallons). This consumption level is less than 0.1 percent of the annual consumption in the State of Nevada. In addition, the repository would use about 2 million liters (530,000 gallons) of hydraulic oil and lubricants, which DOE would recycle.

Materials. For the Waste Retrieval and Storage Area, DOE would build a concrete pad and retrieval support facilities. Construction would require about 600,000 cubic meters (780,000 cubic yards) of concrete and 46,000 metric tons (51,000 tons) of steel, which would not affect the regional supply capacity. About 11,000 concrete storage modules would be required. The concrete would be obtained from offsite sources or the onsite batch plant would be used. The storage modules would be relatively simple concrete vessels with a 0.64-centimeter (0.25-inch) steel liner. About 121,000 cubic meters (158,000 cubic yards) of concrete would be required to build 11,000 modules, which probably would be manufactured commercially. Material usage impacts would be small. The impacts of shipping about 11,000 concrete storage modules to the site would be comparable to those for shipping about 11,000 disposal containers to the site (see Chapter 6, Section 6.1.3).

Site Services. The onsite emergency response capability and the security, medical, and fire protection units that would support operations would be available to support retrieval, so no additional impacts would be likely.

Table 4-58 summarizes impacts to utilities, energy, and materials.

Table 4-58. Utilities, energy, and materials for retrieval.[a,b,c]

	Electric		Fossil fuel		Construction materials	
Location	Peak (MW)[d,e]	Use (1,000 MWh)[f]	Liquid fuels (million liters)[g]	Oils (million liters)	Concrete (1,000 cubic meters)[h]	Steel (1,000 metric tons)[i]
Surface	1.3	83	21	0.034	600	46
Subsurface	7.7	700	0.3	2.2	0	0
Totals	***9.0***	***780***	***21.3***	***2.2***	***600***	***46***

a. Sources: DIRS 104508-CRWMS M&O (1999, pp. I-22 to I-24); DIRS 104523-CRWMS M&O (1999, p. 6-35).
b. All entries except peak electric power are cumulative totals for the entire period.
c. Approximate retrieval period would be 14 years.
d. Peak electric power is the peak demand that would occur during the period.
e. MW = megawatts.
f. MWh = megawatt-hours.
g. To convert liters to gallons, multiply by 0.26418.
h. To convert cubic meters to cubic yards, multiply by 1.3079.
i. To convert metric tons to tons, multiply by 1.1023.

4.2.1.2.12 *Impacts to Waste Management from Retrieval*

The construction of the Waste Retrieval and Storage Area would generate an estimated maximum of 13,000 cubic meters (460,000 cubic feet) of construction debris, 2,800 cubic meters (99,000 cubic feet) of sanitary and industrial solid waste, and 520 cubic meters (18,000 cubic feet) of hazardous waste (DIRS 104508-CRWMS M&O 1999, p. I-22). Based on operations generation rates, retrieval of the waste packages would generate an estimated 4,900 cubic meters (170,000 cubic feet) of sanitary and industrial solid waste. Throughout the construction of the retrieval facilities and retrieval operations, the workforce would generate sanitary sewage. After the spent nuclear fuel and high-level radioactive waste were placed in the concrete storage modules and on the concrete storage pads, waste generation would continue due to the presence of a workforce. Surveillance and monitoring activities would generate sanitary and industrial solid and low-level radioactive waste.

Construction debris and sanitary and industrial solid waste would be disposed of at onsite facilities or at the Nevada Test Site. Sanitary sewage would be disposed of at onsite facilities. Low-level radioactive waste would be disposed of at the Nevada Test Site or another government or commercial facility in accordance with applicable Federal and state requirements. Hazardous waste would be shipped off the site for treatment and disposal at a permitted commercial facility. As discussed in Section 4.1.12, the available capacity for hazardous waste treatment and disposal in the western states would exceed the demand. Assuming this trend would continue, hazardous waste possibly generated during retrieval activities would have a very small impact on the capacity for treatment and disposal at commercial facilities.

4.2.1.2.13 *Impacts to Environmental Justice from Retrieval*

Workers at the Yucca Mountain site would be representative of the population mix in the surrounding areas of Nevada. Hence, there would be no disproportionate impacts to minority or low-income workers in the Yucca Mountain region during retrieval activities. Disproportionate impacts to minority or low-income populations from retrieval construction and operation activities would be unlikely. Impacts to areas of cultural importance to American Indians could vary depending on the conduct of activities and the location of significance boundaries.

4.2.2 IMPACTS FROM RECEIPT PRIOR TO THE START OF EMPLACEMENT

Repository operations would begin after DOE received a license from the Nuclear Regulatory Commission to receive and possess spent nuclear fuel and high-level radioactive waste. For this EIS, DOE assumed that the receipt and emplacement of spent nuclear fuel and high-level radioactive waste would begin in 2010 and occur over a 24-year period (70,000 MTHM at approximately 3,000 MTHM per year), unless surface aging was used, in which case there would be a 50-year operations period. The EIS considers the potential for the transport of spent nuclear fuel or high-level radioactive waste to the Yucca Mountain site several years before the waste was actually emplaced in the repository as a contingency action, not part of the Proposed Action. DOE recognizes that regulatory changes would have to occur for the receipt of spent nuclear fuel and high-level radioactive waste before the start of emplacement, and would have to build a facility similar to that described as part of the retrieval contingency (Section 4.2.1.1) for the receipt of these materials pending their emplacement.

Such a facility would consist of a series of concrete pads in the Midway Valley Wash area (the same area described for the retrieval contingency). The facility would be capable of storing as much as 40,000 MTHM of spent nuclear fuel and high-level radioactive waste in concrete storage modules.

The types of impacts resulting from the construction and operation of a Waste Staging Facility would be similar to those from the implementation of a retrieval contingency, described in Section 4.2.1. The impacts would include land disturbance, emission of particulate and gaseous pollutants, and radiation doses from the handling of spent nuclear fuel and high-level radioactive waste. In all cases, potential impacts would be bounded by those presented for the lower-temperature operating mode in Section 4.1.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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